[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Tuesday, 9 January 2024 8:56 AM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

justin

Family Name

tutty

Location

DARWIN, NT

Stakeholder type

Community member

Email address

justin@darwin.email

Interest area

Social and cultural
Flora and fauna
Waste management
Water
Climate change
Human health

Regulation and compliance
Chemicals
Well integrity
Other (please specify) - the pervasive corruption of democratic process; the vacuum of appropriate policy; extinction

---

Please provide your comments

Please accept the attached objection to the draft EMP for these 'exploration' leases. I'm interested in any further opportunities to contribute to improved decision making around this unwanted industrial threat.

Add an attachment - Max file size: 5MB

https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/9231f9f3a05624e687e9f7b6126b1e446fe3f397/original/1704756330/6204f8702561fd442261677c7b10b6b8_jtnt-objection.pdf?1704756330

Attention: Petroleum Operations unit, Department of Environment, Parks and Water Security

Re: objection to the Environmental Management Plan for the Beetaloo Basin Shenandoah South E&A Program covering “exploration” permits 98 and 117

I object to the finalisation of this EMP because:

- significant areas of harm and community concern are poorly addressed;
- proposed activities extend beyond exploration to encompass commercial production - of particular interest given the volume of environmental recommendations from the scientific inquiry which are required ‘before production’;
- the development of these wells is a significant step towards broadscale exploitation of the Beetaloo Basin, which would be an insult to Nature;
- this in turn will scaffold the greater insult of the Middle Arm Development (MAD) gas precinct, a highly contentious and widely ambitious scheme that would vastly overwhelm NT Governments management capabilities – environmentally, economically and socially.

Process

It is unfortunate that the public exposure period for this process coincides with the corporate shutdown period / x-mess / new years. Personally I devote this time of year to certain traditions that render me unable to concentrate on this task for much of the exposure period. I notice that many friends and neighbours either travel to visit family, or host visitors, consistent with significant NT population sectors, spanning itinerant, seasonal, short-term, FIFO and other Territorians of inter-state origin. Whereas I have been able to compile an inappropriately brief and regretfully incomplete response, I imagine that for many this timing is entirely prohibitive.

I recommend that an extended consultation period be advertised.

Climate impact

Given the limitations posed by poor timing, I will focus on this highly relevant area of significant public concern (unlike the Draft, which affords only minor treatment)

Climate impact has been a sustained focus of ongoing public dissent towards the new industrial threat of shale fracking, recognised as one of five key issues raised by the community through the Pepper Inquiry. These concerns span fugitive methane emissions, cumulative impact from use of shale gas as a source of energy generation and other industrial activities. The inquiry fielded advice that embarking on massive new fossil fuel exploitation is inconsistent with a carbon budget approach to Australia’s international and domestic commitments to emissions reduction.

The Inquiry’s final report assessed the unmitigated risk to climate change for life cycle GHG emissions as moderate to high, contingent on production scale. A range of recommendations (9.1 to 9.7) directly address these, moderating risks associated to methane emissions to a medium rating.

Acknowledging that further mitigation of the risk of methane emissions is necessary, alongside other greenhouse gas impacts, the final report further offered:

Recommendation 9.8

That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT.

Since then there has been considerable ongoing public scrutiny and media controversy over the mechanisms by which governments may attempt to meet this requirement. The Commonwealth and other state governments have publicly denied NT Government claims that other jurisdictions might carry the can for offset costs, which researchers at the Australia Institute warn could rapidly become not only financially prohibitive but also practically unavailable on the domestic carbon market. In recent weeks, a multi-dimensional scandal aired questions as to the role of a gas-industry double agent employed in the (now former) Chief Minister's department in cabinet decisions to abandon an NT policy that would give regulatory form to recommendation 9.8

So it is unfortunate to find this focus of ongoing dissent and controversy is afforded scant attention in the draft EMP.

Section 2 of the draft, Environmental legislation and other requirements, identifies no relevant NT requirements. Unfortunately, this appears to be an accurate reflection of the regulatory context.

The NT still has no Climate Change Act. A prior draft of the *NT Climate Change Response - Towards 2050* report warned that emissions may peak after 2030. This detail is missing from the final published version. With that amorphous waypoint removed, Territorians, and prospective polluters, have no visibility of when the inflection point from "boundless possible" to economy-wide emissions reductions will be realised.

So it is understandable the EMP makes no reference to the *Towards 2050* report. Neither does it reference the *NT Large Emitters Policy*. Again, this is accurately absent from the audit of relevant regulation, as all this policy requires is that polluters nominate their scope, and having 'a plan' (GGAP) to either

- commit to an overarching target of net zero emissions by 2050 (I'll be retired by then. Will you?); or
- give a good excuse why not.

The EMP does make passing reference to a GGAP, though it is not included as an associated document. So Tamboran appear to be confident that this instrument (EMP) may be finalised in the absence of a required management plan (GGAP) for one of the most controversial and impactful environmental harms.

Absent any relevant NT regulation, and without visibility of their GGAP, we have, from Table 1, and Table 9, three main points for managing that impact to *Peak residual emissions of 83,692 tCO2:*

- All emissions in an FY will be offset where the 100K tCO2 safeguard trigger is exceeded
- Tamboran will offset a % of residual emissions in alignment with the NT Net Zero Policy
- The beneficial use of appraisal gas (outside of this EMP) will be used to manage emissions beyond FY 25 (subject to additional regulatory approvals)

The first is a commitment to follow Federal law. Well, good-O. The second is unbounded: but in fact, a zero per cent offset would not be out of alignment with NT policy.

That third point is cryptic, and demands far greater scrutiny than the Draft offers. On the face of it, we are invited to credit an action inconsistent with the leases' purpose, and held explicitly outside the Draft and associated management plans, as a meaningful contribution to managing a significant harm under the EMP for these EPs.

I strongly oppose the recent regressive legislation which invites this wilful blurring of the modes of exploration and production. Yet given this regrettable context, it remains outrageous to consider the EMP could be finalised with this, the single-most significant management proposal for the highly controversial feature of climate impact, withheld explicitly outside the Plan. This action requires further definition, including contingencies, particularly for the highly likely scenario that arrangements for on-selling appraisal gas run behind the exploration schedule.

Discussion about life cycle analysis and sea dumping are specious, irrelevant and kinda cringe. I guess that's what the aforenoted '*give a good excuse why not*' clause from the toothless Large Emitters Policy gets us.

So we are told:

> *In a development scenario, gas production is likely to have 50% less emissions than coal, thus playing an important role as a transition or firming fuel to support large scale renewable energy supply.*

- as if that means something.

What coal? What role? Well, who cares. You only asked for a story, so that's all you got. Also:

> *Scope 3 emissions will also be reduced through investigation in low emission technologies, such as carbon capture and sequestration (CCS) enable blue ammonia/ hydrogen and electricity export.*

What investigation? When? Where? And most confusingly, how does mere investigation reduce emissions? I'd hate to be the one tasked to connect those dots. But I won't be: no one will be. It's a vibe thing. These are merely the valuable platitudes demanded by NT policy.

Tamboran's own corporate Climate Policy, also unreferenced by the Draft, commits to:

> *Promote the use of new technologies and renewable energy*

however their

> *ongoing commitment to invest in ... renewable energy sources*

is not evident in the Draft.

Tamboran could at least consider the alternative of solar vs diesel to power enhanced evaporation

Not just actions, also proposed monitoring is vastly inadequate for what is a major risk and highly controversial feature of this new industrial process.

The Draft only addresses monitoring emissions at infrastructure (flares, vents and leaks) and of these, only leaks require a response. 6 monthly leak detection of surface infrastructure is grossly inadequate. The response for minor leaks has no escalation / contingency: this could result in 5.30 months of unaddressed major leak.

Instead, Tamboran should implement as standard continuous monitoring of infrastructure. Point based instruments can effortlessly implement continuous methane monitoring with accurate, validated measurements at scale. Events from this monitoring can gather data on trends, trigger investigations on incidents and shore up estimates.

The EMP notes that

> *In addition to monitoring emissions from drilling, stimulation and well testing activities, baseline assessments have been completed by CSIRO in the vicinity of the lease pad*

But to what end? The Draft offers no detail of further landscape measurements, only infrastructure. But fugitive emissions are not limited to infrastructure.

The SREBA describes:

> *natural surface emissions of greenhouse gases from Beetaloo Sub-basin formations.*

Tamboran's activities may exacerbate these existing natural GHG sources, or open new ones.

The SREBA identified options for regional surveys, mobile and static, combining *"optical gas analysers ... to continuously measure ambient methane concentrations"*, and *"flux chambers to measure the flux from possible geologic seeps"* – yet the Draft is silent on landscape monitoring.

GISERA have set a standard, deploying ground based stations for continuous monitoring of atmospheric greenhouse gas concentrations in the Surat Basin to estimate fluxes (primarily methane) from the region. Tamboran should pursue best-in-class practice for monitoring landscape-wide emissions associated with these Beetaloo leases. Exploration is by definition a more experimental industrial phase. It is therefore highly appropriate that Tamboran should be more curious about any impact their activities may have on landscape-wide fugitive emissions.

Other notes

Clearing:

We are given an unhelpful description of clearing as

> *0.019% of the combined surface area*

of the EP leases. Obviously a circle that size would have far less impact than the proposed activities will present.

The proponent should report perimeter, to provide a meaningful measurement.

We are assured

> *most areas will naturally regenerate following rehabilitation following the wet season,*

with no reference to contingency, nor revegetation of those areas not expected to naturally bounce back.

The proponent should describe alternative measures for revegetation, or at least estimate the anticipated scope of un-rehabilitated impact.

Stormwater:

The management of stormwater is inadequately defined. Stormwater features in neither the process water balance nor the wastewater balance. Capacity of stormwater basins should be reported.

Seismic:

We are given:

> *If the use of dynamite is not feasible, vibroseis trucks will be used for the seismic source.*

The proponent should provide an estimate for how many trucks may be used, at how many sites

Groundwater:

The list of sensitive receptors should not ignore groundwater. The draft provides no monitoring for regional groundwater beyond the well-head, and the only control action is well casing and cementing.

The proponent should monitor for and pursue water quality and draw down standards elsewhere on the leases.

Stygofauna:

The Pepper inquiry deferred concerns about impact on Groundwater Dependent Ecosystems to the regional SREBA. Along the way, discoveries were made regarding the presence of stygofauna in the Basin, which both represent a sensitive receptor, and illustrate the interconnected nature of regional reservoirs.

The Beetaloo SREBA did not provide any further certainty about GDE impacts, which were classified undetermined. Yet the Draft appears to reclassify these risks as low, without any further research. Absence of evidence is insufficient grounds to shirk further monitoring.

Threatened fauna:

The decision that

> *During the dry season, flowback will be treated in open treatment tanks to reduce the wastewater volume as much as possible.*

is at odds with exploration of the inquiry into the likely impact on local fauna, which recommended:

> *that enclosed tanks be used to hold wastewater in preference to open ponds (Recommendation 7.12), which would prevent access by wildlife.*

- without any equivocation about evaporation.

This is widely recognised by participants as an unmet recommendation.

The proposed objective:

> *EC-2 – EC-3: <7 individual fauna deaths per week for 2 consecutive weeks caused by flowback water storage*

is alarming. A perverse reading could see this as pursuing unbounded killings by alternate weeks. Perhaps by covering the evaporation ponds every other week. Disgust at abandonment of recommendation 7.12 aside, Tamboran could at least arrive at a less objectionable schedule.

Waste water management:

We are informed that

> *Scaling constraint posed by wastewater restricted the use of conventional water treatment*

and

> *flowback may be reused in the stimulation make up fluid where technically feasible*

but the Wastewater Management Plan tells us that

> *Drilling, completion, suspension and kill fluids*

will be

Transferred to flowback storage facilities

The claim

salinity and scaling constrain the use of conventional water treatment.

seems inconsistent with other NT resources activities.

The proponent should explore potential benefits of quarantining the high-volume production water waste stream from this smaller volume of wet wastes (up to 1ML/well) with higher salinity / EC. This could help maximise compatibility of stored water for reuse, and facilitate alternative management options. The smaller volume of higher salinity waste may then be amenable to conventional treatment. Tamboran could reassess the viability of extending water treatment to the entire stock of waste water.

Erratum

APPENDIX G Wastewater Management Plan on p11 details

Drilling, completion, suspension and kill fluids

as

KCl or NaCl based fluids with a TDS >50,000 us / cm

but TDS is Total Disolved Solids, which are measured as grams per litre. This probably refers to electro-conductivity, which as described in *Appendix J Water Monitoring Suites* is measured in siemens per metre

References

as described.

Contact

Justin Tutty
25 Kapalga St, Tiwi
justin@darwin.email

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Tuesday, 9 January 2024 11:17 AM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Reanna

Family Name

Bathern

Location

TENNANT CREEK, NT

Stakeholder type

Landholder/occupier

Email address

rbathern@hotmail.com

Interest area

Other (please specify) - I am a Djingulu woman. My family go back generations on Beetaloo station. It is my mothers fathers country. I return to my country often. Our family storylines, both Indigenous and non indigenous go right through this country. My childhood was spent here only leaving due to family sickness.

Please provide your comments

This is very emotional for me. In my childhood I lived on the shores of Longreach waterhole with older women for weeks camping throughout my childhood. It is critical this place is not disturbed. We have a responsibility to be caretakers of this land. I worry about what this industry will do to the land. We have grown up on this land, enjoyed this country, it is a deep connection. Country is about spiritual wellbeing. We return there to rejuvenate and connect and water is a big part of that reconnection. We grew up eating mussels and they are good food and also a strong medicine for us. My Nanna used this medicine and lived to the age of 97. We also get Geenie, a small catfish in these waterways. We eat the fish whole. I worry about these foods being contaminated from fracking. I also worry about the birds. They live in and fly through theses places. They live close to these fracking fields. I worry for the goanna who need this water too. I worry my country will never be the same after these fracking companies have come. Other members of my family have wanted to contribute to this process. There has not been enough time in this EMP process. We have been let down by NLC in terms on consultation about these planned wells. Not enough platforms are used to advertise these plans. This is unfair to people who want to fight to keep their country safe. Our land is a living and breathing thing. The Northern Territory is our children's future, it is their home, but I worry for what we are leaving our future generations. We need our connection to country for our wellbeing. Our people are being bought, but at a huge cost to our culture. The processes have been rushed. It isn't fair.

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Friday, 5 January 2024 5:50 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

TORRENSVILLE, SA

Stakeholder type

Community member

Email address

[redacted]

Interest area

Flora and fauna
Social and cultural
Water
Waste management
Climate change
Human health

Chemicals
Regulation and compliance
Well integrity

Please provide your comments

Fracking is long term pain for communities, ecologies… it poisons water and land. Please… keep Beetaloo safe for all life. We don't need gas that badly. There are other cleaner eco friendly ways to create energy/fuel. Have respect for all life.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Friday, 5 January 2024 2:14 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Jaemie

Family Name

Page

Location

DARWIN, NT

Stakeholder type

Landholder/occupier

Email address

jaemie.page@iinet.net.au

Interest area

Social and cultural
Flora and fauna
Waste management
Chemicals
Climate change
Regulation and compliance

Water
Human health
Well integrity

Please provide your comments

Fracking is ridiculous. We all know the rapidly increasing effects of climate change caused by fossil fuels to continue is criminal negligence. Plus we dont want water contaminated, weeds spread, land destroyed by wells and access roads. The UN and many others have called for an immediate end to new fossil fuel projects. NT will be liable for damage.

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Wednesday, 3 January 2024 10:09 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

NAKARA, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Climate change
Regulation and compliance

Please provide your comments

Over the four years of this proposed project Tamboran expects to emit 421,663 tCO2 -e and is expected to "offset" only half these. Under the Pepper Report and committed recommendations ALL carbon offsets are to be off set, this is a commitment to the people of the NT by the NTG. I object to this fracking expansion based on the fact that not all Pepper Report recommendations have been

---

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

From:	Have Your Say Northern Territory
To:	tamboran DEPWS
Subject:	Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan
Date:	Thursday, 14 December 2023 5:35:37 PM

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Given name

[redacted]

Family Name

[redacted]

Location

NGUKURR, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Water
Climate change
Regulation and compliance
Human health

Please provide your comments

Please slow down your decision making until 2024 after the Christmas holidays. It's quite a cheeky and low level action to rush through this process.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Monday, 8 January 2024 12:46 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Miliwanga

Family Name

Wurrben

Location

KATHERINE EAST, NT

Stakeholder type

Community member

Email address

wmiliwanga@gmail.com

Interest area

Social and cultural
Water
Climate change
Chemicals
Well integrity
Regulation and compliance

Human health
Waste management
Flora and fauna
Other (please specify) - Traditional elder and healer

Please provide your comments

see attachment

Add an attachment - Max file size: 5MB

https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/ff690973cd2ed1607368c1de2a6a0d2b6b1ae88c/original/1704683750/760fb30afd521472aeac32f6624910af_Miliwanga_Wurrben_Tamboran_EMP_2023.docx?1704683750

My name is Miliwanga Wurrben, I am an elder of the Rembarrnga tribe. I am seen as a traditional healer, a traditional herbalist, and a traditional cultural consultant. In my work I am also an advocate, not only for my tribe, but also for all my people that need help to consult and mediate with various Western organisations. I am speaking on behalf of our people about water and the land and what it means to us. The true deep understanding of Aboriginal Law has not been considered in this Tamboran Plan or at any time in the story of fracking and mining in the Northern Territory. This is not good enough. It is important that Aboriginal cultural and spiritual values of water and land are deeply considered, especially now, with the changes we are already seeing in our environment with climate change.

Our land is our life. Our water is our life. It is the most sacred thing to us. The water, the land, everything above and below. Our relationship to land is governed by our law. We abide our law that was passed down by our ancestors from long ago. We have Law of the Land, and Law of the Water. Everything the Law holds we must abide by. Your water policy, your Land Rights Act, these did not exist previously in our culture. We have our own Water Policy and our own Land Rights Act.

Our land is very sacred. So is our water. We have traditional songs and dances where we acknowledge our ancestral spirits of the land, those that help care for the land, water, animals, and all of us. We work together, taking care of the land and the waterways. By doing this we are keeping the environment going. We must let the water run naturally. This makes sure the land can feed the animals and itself. To not do this is taboo for us. Everything we do is by order of the Law that we abide by.

No one has ever come to sit with us and go through these mining processes they are talking about, seeing it through the eyes of our Traditional Law. They need to look at fracking using our laws, what our laws say for land and water and people. How we are all connected. No one has come and truly sought advice from our people, advice that would help them understand how it is so sacred to our people. It is high time that our government should come out, sit under the shade of a tree, and talk to us. To hear our voice. To hear and respect the Laws of the Land, and to hear and respect the Laws of the Water and what it holds. It is so dear to us. Destroying the land and the water will also destroy First Nations people, and all the living things that we need for food. It is all connected. It holds our cultural integrity.

It is important that Westerners understand that when one part of the land is damaged and destroyed elders, even children, babies, and adults feel deeply sick inside. This is true. Damaging the land makes us sick. We have had many elders who have passed on because the mining place is actually on their dreaming place, their totem, the place that unites them together with the land. To damage country is like tearing a child from their mother. This document that speaks of more fracking does not consider the cultural trauma that is happening because of this mining. The ongoing trauma and sickness that spreads from these actions.

Chronic illness is very high among our people. You think this is normal, but it is not. We have never experienced this before. It is new and rapidly moving. Cancer, dialysis. So many deaths from blood poisoning. If only you could see the background of what is causing these

illnesses, then you will surely know where it comes from. This stems from mining. Mining is actually destroying the land along with the water. That destroys the people of the land themselves. Tribal people wherever we are, we feel the pain of what is being mined. We feel the pain not only physically but spiritually. And you wonder why those elders pass on. Now we also know this mining includes poisonous chemicals. The poison chemicals will eventually destroy the entire environment, animals, all people. Our tribal land will not function naturally as it did before. It makes me deeply sad to consider this. Tamboran have not considered how their actions take away from our culture and break our Law.

They are talking about using hundreds of millions of litres of water every year, knowing it will all be poisoned. We know spills happen. We know companies dump their poison water. We have seen it all before. If we keep doing this, we will eventually be drinking poison water. At first it will be the tribal people living in and around that area. But these underground aquifers flow towards us further North. The water flows to us through our great rivers. The Katherine, Roper, Elsey, Daly, and Victoria Rivers. All the poisons can end up in these rivers. These rivers mentioned are very sacred.

This water that these fracking companies want to poison unites people living along the whole underground aquifer and river. It runs through one tribal land to another tribal land, yet it is the same water, the same river, the same Law that people live by. It makes our people one. The importance cannot be understood if you have not lived with this as your Law. The same law governs the land and water, across tribal boundaries. It has always been so. This Native Title Law does not speak for our water. Our Traditional Law speaks for water. It needs to be heard.

Traditionally there are songs sung for these rivers. The most significant places are where the underground aquifers emerge in springs. This is where the spirit beings of the water live. Anything that disturbs the flow of water through those springs will create natural disasters, massive floods, or long droughts. Animals and plants and even people around those springs will suffer serious consequences. This underground water constantly fills out springs. All those spiritual beings that live there work together to keep water flowing. And if anything does happen to the spring, serious consequences will fall on the people that destroy it. There are stories from all over about this happening. It has happened in our area too. The Law is to not tamper with or touch the sacred springs, for we know what it will bring.

Our belief is strongly held, built from thousands of years of experience, and needs to be respected. People need to acknowledge what it there. This is our unique reality. It is our creation. We speak to the water, and it speaks to us. We hold it deep in our hearts. Water is a living thing. We have customary law about what we must and must not do with the water. We do water blessings. We call to our ancestors and the water guardian spirits. This is all part of our water policy, our Law.

When we hear that water will be pulled up from underground and poisoned by Tamboran it breaks our heart the proper way.

Consultation process for this fracking must take place in a way that honours our Law, not new Western Law. Traditional consultation is where both tribes sit together with their elders and talk about things that are happening or will happen on somebody's country. It is very important for our people to understand what is truly happening on their country, and to always have an elder and a Junggayi present to hear and explain any issue that concerns our people.

Many people still do not understand what fracking is. It has not been explained to them fully. It has not been explained in language. Letters are not explained or read to people; interpreters are not present. Aboriginal liaison officers, who truly know our culture, are often not present to sit with our people. A lot of the times the right protocols are not used. A lot of the mining work in the Northern Territory has gone through without our people knowing or being told about what is happening, or what the project would look like in the future. A lot of the time elders have signed off on their land without full understanding of the mining company's intentions. A lot of the elders have passed and yet their signatures remain on those letters they have signed. We know now it was an agreement to go ahead with mining and fracking on their country. Agreements they did not fully understand.

And we cannot talk about fracking without talking about climate change. Traditionally speaking of climate change, we, the people of the land, can tell when there have been changes made in the weather and season. The seasons let us know when things are not right. For example, fruits and yams that we recognise always come up at the right time and season. Harvesting those foods has always been at the right time. When there are fruits and yams grown that come up in the wrong season then we know for sure something is not right. We cannot eat food that comes up at the wrong time. We do not touch this food then. It is not culturally appropriate.

We also see disasters such as storms, with strong winds, lightening that comes at the wrong time and we understand that something is wrong. These things we see take us back to what is happening on the land. We take this back to see what is destroying sacred ground. This is the mining, and now this fracking.

We understand this climate change. We have flowed with all of this since the beginning. Our ancestors followed the same system of harvesting and replanting yams. The have helped to look after the land while the land looked after them abundantly, along with the animals.

This fracking, using tonnes of water, will eventually cause climate changes. We must have consultation before any mining takes place about this issue of fracking. Traditional owners of the land must understand and know what climate change is and how fracking can make climate change happen. If we do not stop it, then climate change will become much worse than before.

People from all over Australia are working to regenerate our environment. Moreover, we have men and women rangers who are constantly working to care for the land of our tribal people. Their job is to make sure water is flowing free. To make sure that everything in the land is intact. These are the rangers from the desert to the salt water, from east to west. They have been taking care of their land, making sure their environment is in good

condition. This helps to slow down the climate changes, but we need more hands in taking care of this land, like we used to before.

Traditional people all over the world are standing up to care of their lands, regenerating the plants even on deserted mining places. A lot of our old mining places here no one has ever had the feeling of putting back and restoring what has been destroyed. This lessens climate change and for us it means we can harvest foods at the right time again. It helps the land to reproduce and give back to the people. When the people help mend the land the land gives back to us. With this work we will see the seasons restored to their own cycle.

These new wells that Tamboran wants to build will do more damage. Traditionally speaking this is very bad for us the people. They tamper with the water below. We fear the outcome it will bring. We fear a great disaster. This will surely affect the people, the animals, the plants, and everything, not only below but above as well. It is very important in our belief that we do not tamper with sacred waters from underground. We need to make sure the springs will never run dry for us. If these are destroyed it will destroy us as people. If it is poisoned, we, the plants, and the animals take that poison into us.

We communicate with all living beings. I hope that you all see this great connection with the land, the water, and the environment. It makes us who we are. If they are destroyed, we are also destroyed. The impact of this industry on our culture and our well-being must be considered. This is not about native title holders; it is about the original Law that we abide by. It was here before these new laws came and to this day, we still hold this Law.

Everything we see in life has a balance. The cycle of seasons. The nature. The people. The stars above. And the earth below. It all has a balance. Now we know even carbon has a balance. If we do not maintain this balance all things will be lost either through mining or pollution, or climate change. Poisoning the water, the land, the air; it is actually poisoning all mankind.

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Monday, 8 January 2024 11:55 AM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

MOUNT ISA CITY, QLD

Stakeholder type

Community member

Email address

[redacted]

Interest area

Other (please specify) - My family has history and culture deeply connected to this land and water. We have family members living in Elliott and ancestors buried in marked and unmarked graves on Beetaloo Station. Our documented family history began on the waterways of Beetaloo Station which connect to the waterways of these fracking leases. Our great grandfather married our great-grandmother. She took him to the water of Beetaloo Station. This established the station. My grandmother is buried at Lilyhole Creek, and my grandfathers side are buried at Beetaloo Station.

Please provide your comments

Exploration worries me in that cultural sites and unmarked graves will be disturbed. In the EMP it says there is not an AAPA clearance in place. It is essential full clearance walks are conducted on the whole site before any work is considered. Each clan group must be represented in this process and it must include all waterways downstream of the exploration sites. Proper consultation is not occurring with traditional owners. The future of our land, and the Northern Territory is being damaged by these practices. I worry for the future of my children, grandchildren and great grandchildren. I want them to be able to go onto the land and get bush tucker and experience culture like we have. This will become non existent if these fracking practices continue. I also worry about the health outcomes for future generations that use this water and live near these sites. Why were all traditional owners not notified about the commencement of this exploration? I live a 12 hour drive away from where these meetings are held. I have given personal details to NLC and asked to be included in these meetings. I have received nothing about these meetings. I have received nothing from their administrations. I have had not contact from NLC since April 2023. We used to hear from family in Elliot when they are notified of planned meetings but this only occurs in the same week as the meeting itself. It is impossible for us, working interstate, to make these meeting or even hear about that meetings are taking place. I have no faith in the anthropology that is dictating traditional ownership across this region. There needs to be a lot more work in this area before such a big industry arrives. It needs to be done while the old people are still around. Everybody needs to be considered. A lot of people remain totally unaware of what is going on. The NLC are not consulting people across the board. These companies are coming in and making dollars, NLC get their cut but what is coming back to our community? People are still starving and living in deplorable housing. Many people do not understand what is being planned and are being bought off with relatively small amounts of money. I am appalled by the lack of support being given to people on the ground, the percentages being skimmed off from royalties and what the executive is being paid. They get on side with people they can coerce and do not talk to other people.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Monday, 8 January 2024 10:22 AM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

ELLIOTT, NT

Stakeholder type

Landholder/occupier

Email address

[redacted]

Interest area

Other (please specify) - Tradtional Owner

Please provide your comments

I am Janey Dixon. I am from Marlinja Community. I have lived here almost my whole lifetime. My biggest concern with this EMP is about the water. Water is our life. It has everything, it has a living creature inside of it. This keeps it really sacred. The watercourse from these fracking wells goes right through to Marlinja, Longreach and Lake Woods. These watercourses have our culture deep in them. We use them and their mud for culture. I do not want fracking. It will damage our water and our environment and the whole area that we live in. It's not good to have fracking in areas that we are close by to and that we share water with. The effect of the fracking will spread to our animals, birds, trees - these are all living things that have shared this area with us for a very long time. Fracking could destroy this. The living creatures do not know what is going on and we are speaking for them too. It is really hard and sad for these living creatures and human beings.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Saturday, 6 January 2024 9:03 AM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Harold

Family Name

Dalywaters

Location

ELLIOTT, NT

Stakeholder type

Landholder/occupier

Email address

hdalywaters@y7mail.com

Interest area

Social and cultural
Water
Climate change
Chemicals
Well integrity
Regulation and compliance

Human health
Waste management
Flora and fauna

Please provide your comments

I am Harold Dalywaters. I am a native title holder for Shenadoah Station. The proper consultation has never happened for fracking on our country. Our people still do not know what the risk of this industry are. We all need to be on the same page about what will happen to us and what our future will be. We don't want the wool pulled over our eyes and for future generations to suffer. I want proper consultation. We need an independent person to teach us what this industry is and what the risks attached to it are. We all need to be on the same page with the long term effects of this industry. We have heard a lot of promises for a brighter future from these companies and the government. But we are worried about the cost to the environment and the health of our people. We must protect our future. In that region there are 2 very important sacred sites. We do not have faith that these sacred sites can be protected properly. The Bama-nga-ja site on the North East side of Hayfield is walanja kujika dreaming. On the Western side is Kinmininku kujika dreaming. These are both on big water flats. We are concerned that poisons from the fracking wells will flow to bucket bore and onto Lake Woods. Protecting our culture is the most important thing.

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Friday, 5 January 2024 8:28 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Gabrielle

Family Name

Smith

Location

RAPID CREEK, NT

Stakeholder type

Community member

Email address

gabrielle.skuja@gmailc.om

Interest area

Social and cultural
Chemicals
Climate change
Regulation and compliance
Water
Human health

Well integrity
Flora and fauna

Please provide your comments

I strongly disagree with fracking in the Beetaloo basin, fracking is not a renewable energy, it is a fossil fuel and has high carbon emissions. Fracking will increase climate change and make the climate in the territory unliveable. Please see UN Rapporteur;s comment about the effects of climate change in the NT. Tamboran's fracking project is a feed stock for the middle arm project, these projects will cause environmental devastation and are not financially viable without tax payer dollars. https://www.abc.net.au/news/2023-09-14/united-nations-criticism-nt-projects-middle-arm-beetaloo-basin/102856346 The Territory government and the federal government are not be able to regulate this project because they are too close to the gas lobby. Some parliamentarians retire and go straight to corporate jobs in the gas and mining industry. Both NTG and Federal government have wasted voters trust as they are too close to these industries. The Australia Institute research into the mining and gas industry uses ATO data which shows that these projects don't employ many people locally as these employees move around FIFO ing because they are specialised jobs., That data also showed how little corporate tax Tamboran and other multinationals pay, its appalling. The other important issue is the water, fracturing the rock which houses the aquifiers, is dangerous. Any government that trusts a multinational company with water security is negligent. Tamboran is a corporation whose business is polluting, it is a business that is based on climate change denial and disinformation, they are a danger to democracy. Please read about Tamboran's expansion into Ireland, where the Irish community decided to ban fracking. https://www.irishtimes.com/news/politics/oireachtas/ireland-joins-france-germany-and-bulgaria-in-banning-fracking-1.3137095 Tamboran have no interest other than profit, they are a multinational with no homeland, they just exploit where ever they are allowed access. I strongly disagree with allowing them access. https://australiainstitute.org.au/post/what-transition/ https://australiainstitute.org.au/report/gas-bagging/

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Friday, 5 January 2024 7:09 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

[redacted]

Family Name

[redacted]

Location

RAPID CREEK, NT

Stakeholder type

Community member

Email address

[redacted]

Interest area

Social and cultural
Flora and fauna
Water
Climate change
Human health
Chemicals

Please provide your comments

I am concerned that fracking has started in the NT. What has been proven unsafe and inefficient elsewhere has been foisted on the NT. Our magnificent and ancient aquifers are endangered by these climate destabilising practices. The frack dams place our birds at risk. This is not caring for country. Fracking must stop.

Tick this box if you wish for your name and contact details to be confidential

Make my name and contact details private

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Friday, 5 January 2024 6:48 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Andrew

Family Name

Arthur

Location

JINGILI, NT

Stakeholder type

Community member

Email address

entertain.nt@gmail.com

Interest area

Social and cultural
Flora and fauna
Water
Waste management
Climate change
Human health

Chemicals
Regulation and compliance
Well integrity

Please provide your comments

Clearly the science says the world must have no new fossil fuel projects. If you are going to ignore the International Energy Agency and the Intergovernmental Panel on Climate Change, it’s an absolute farce that you would listen to anyone else! You cannot even follow the recommendations of the NTG Pepper Inquiry. Which (by the way) where committed too. So pat yourselves on the back for reaching out, and take the money at the expense of life as we know it.

From:	Nurrdalinji Contact
To:	tamboran DEPWS
Subject:	Beetaloo Basin Shenandoah South E&A Program EMP (TAM1-1) EP 117 and EP 98 (EMP)
Date:	Tuesday, 19 December 2023 9:05:33 AM
Attachments:	231214_Mark Raymond sub Shenandoah South E&A Program EMP (TAM1-1) EP 117 and EP 98 (EMP).pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please find attached submission on behalf of Mr Mark Raymond, Director.

Regards
Samuel Sandy
Chairperson

11 Skipper Street
Tennant Creek 0860 NT
14 December 2024

Department of Environment, Parks and Water Security
Petroleum Operations unit
PO Box 3675 Darwin NT 0801

By email: TAM1.EP98+117@nt.gov.au

Beetaloo Basin Shenandoah South E&A Program EMP (TAM1-1) EP 117 and EP 98 (EMP)

I am a senior elder and registered native title holder who has a direct interest in the country affected by Tamboran Resources' proposal for work as outlined in this EMP.

I first want to make a comment about the timing of this EMP. It is wrong for the government to put it out at this time of year with such a small time to comment, people are travelling and visiting family. We are busy with our ceremony.

It is also wrong for Tamboran Resources to claim in this EMP that they have properly consulted with us. They haven't. The government and the Northern Land Council are also lying when they say they have consulted with us.

The Northern Land Council has not consulted properly with me, my family or other registered native title holders. The NLC has not provided clear information about Tamboran's plans and risks.

Tamboran and the Northern Land Council do not talk or listen to the group, they talk to a handful of individuals. We have a lot to say about mining companies such as Tamboran Resources coming in and ruining our country. Tamboran should be talking to all the native title holders in the Beetaloo Basin, from Mataranka down to Elliott and across to Borroloola. There should be a big meeting, organised by the NLC, to discuss this matter if they are going to put in 15 news wells.

Recent incidents where Tamboran polluted from one exploration well at Tanumbirini Station make me sad. I have two totems up that way. Tamboran has already been fined for polluting my country. They should not be given approval to drill even more wells. Drilling and fracking, including during the wet season, risks poisoning our sacred waterways which run right across the Beetaloo Basin.

It is also wrong for the cultural surveys done for this EMP to not include my father, Pompey Raymond, a senior elder with responsibility for the country that is the subject of this EMP.

I don't want any fracking anywhere. I don't want that to be my legacy for my grandchildren, I want them to know the country and protect it.

Yours faithfully,



Mark Raymond

[redacted]

From: justin T NT <justin@darwin.email>
Sent: Monday, 8 January 2024 11:14 PM
To: tamboran DEPWS
Subject: Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan
Attachments: jtnt-objection.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Attention: Petroleum Operations unit, Department of Environment, Parks and Water Security

Re: objection to the Environmental Management Plan for the Beetaloo Basin Shenandoah South E&A Program covering “exploration” permits 98 and 117

Please accept this objection to the draft EMP for these 'exploration' leases.

I'm interested in any further opportunities to contribute to improved decision making around this unwanted industrial threat.

justin <*> 0424-028-741

Attention: Petroleum Operations unit, Department of Environment, Parks and Water Security

Re: objection to the Environmental Management Plan for the Beetaloo Basin Shenandoah South E&A Program covering “exploration” permits 98 and 117

I object to the finalisation of this EMP because:

- significant areas of harm and community concern are poorly addressed;
- proposed activities extend beyond exploration to encompass commercial production - of particular interest given the volume of environmental recommendations from the scientific inquiry which are required ‘before production’;
- the development of these wells is a significant step towards broadscale exploitation of the Beetaloo Basin, which would be an insult to Nature;
- this in turn will scaffold the greater insult of the Middle Arm Development (MAD) gas precinct, a highly contentious and widely ambitious scheme that would vastly overwhelm NT Governments management capabilities – environmentally, economically and socially.

Process

It is unfortunate that the public exposure period for this process coincides with the corporate shutdown period / x-mess / new years. Personally I devote this time of year to certain traditions that render me unable to concentrate on this task for much of the exposure period. I notice that many friends and neighbours either travel to visit family, or host visitors, consistent with significant NT population sectors, spanning itinerant, seasonal, short-term, FIFO and other Territorians of inter-state origin. Whereas I have been able to compile an inappropriately brief and regretfully incomplete response, I imagine that for many this timing is entirely prohibitive.

I recommend that an extended consultation period be advertised.

Climate impact

Given the limitations posed by poor timing, I will focus on this highly relevant area of significant public concern (unlike the Draft, which affords only minor treatment)

Climate impact has been a sustained focus of ongoing public dissent towards the new industrial threat of shale fracking, recognised as one of five key issues raised by the community through the Pepper Inquiry. These concerns span fugitive methane emissions, cumulative impact from use of shale gas as a source of energy generation and other industrial activities. The inquiry fielded advice that embarking on massive new fossil fuel exploitation is inconsistent with a carbon budget approach to Australia’s international and domestic commitments to emissions reduction.

The Inquiry’s final report assessed the unmitigated risk to climate change for life cycle GHG emissions as moderate to high, contingent on production scale. A range of recommendations (9.1 to 9.7) directly address these, moderating risks associated to methane emissions to a medium rating.

Acknowledging that further mitigation of the risk of methane emissions is necessary, alongside other greenhouse gas impacts, the final report further offered:

Recommendation 9.8

That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT.

Since then there has been considerable ongoing public scrutiny and media controversy over the mechanisms by which governments may attempt to meet this requirement. The Commonwealth and other state governments have publicly denied NT Government claims that other jurisdictions might carry the can for offset costs, which researchers at the Australia Institute warn could rapidly become not only financially prohibitive but also practically unavailable on the domestic carbon market. In recent weeks, a multi-dimensional scandal aired questions as to the role of a gas-industry double agent employed in the (now former) Chief Minister's department in cabinet decisions to abandon an NT policy that would give regulatory form to recommendation 9.8

So it is unfortunate to find this focus of ongoing dissent and controversy is afforded scant attention in the draft EMP.

Section 2 of the draft, Environmental legislation and other requirements, identifies no relevant NT requirements. Unfortunately, this appears to be an accurate reflection of the regulatory context.

The NT still has no Climate Change Act. A prior draft of the *NT Climate Change Response - Towards 2050* report warned that emissions may peak after 2030. This detail is missing from the final published version. With that amorphous waypoint removed, Territorians, and prospective polluters, have no visibility of when the inflection point from "boundless possible" to economy-wide emissions reductions will be realised.

So it is understandable the EMP makes no reference to the *Towards 2050* report. Neither does it reference the *NT Large Emitters Policy*. Again, this is accurately absent from the audit of relevant regulation, as all this policy requires is that polluters nominate their scope, and having 'a plan' (GGAP) to either

- commit to an overarching target of net zero emissions by 2050 (I'll be retired by then. Will you?); or
- give a good excuse why not.

The EMP does make passing reference to a GGAP, though it is not included as an associated document. So Tamboran appear to be confident that this instrument (EMP) may be finalised in the absence of a required management plan (GGAP) for one of the most controversial and impactful environmental harms.

Absent any relevant NT regulation, and without visibility of their GGAP, we have, from Table 1, and Table 9, three main points for managing that impact to *Peak residual emissions of 83,692 tCO2:*

- All emissions in an FY will be offset where the 100K tCO2 safeguard trigger is exceeded
- Tamboran will offset a % of residual emissions in alignment with the NT Net Zero Policy
- The beneficial use of appraisal gas (outside of this EMP) will be used to manage emissions beyond FY 25 (subject to additional regulatory approvals)

The first is a commitment to follow Federal law. Well, good-O. The second is unbounded: but in fact, a zero per cent offset would not be out of alignment with NT policy.

That third point is cryptic, and demands far greater scrutiny than the Draft offers. On the face of it, we are invited to credit an action inconsistent with the leases' purpose, and held explicitly outside the Draft and associated management plans, as a meaningful contribution to managing a significant harm under the EMP for these EPs.

I strongly oppose the recent regressive legislation which invites this wilful blurring of the modes of exploration and production. Yet given this regrettable context, it remains outrageous to consider the EMP could be finalised with this, the single-most significant management proposal for the highly controversial feature of climate impact, withheld explicitly outside the Plan. This action requires further definition, including contingencies, particularly for the highly likely scenario that arrangements for on-selling appraisal gas run behind the exploration schedule.

Discussion about life cycle analysis and sea dumping are specious, irrelevant and kinda cringe. I guess that's what the aforenoted '*give a good excuse why not*' clause from the toothless Large Emitters Policy gets us.

So we are told:

> *In a development scenario, gas production is likely to have 50% less emissions than coal, thus playing an important role as a transition or firming fuel to support large scale renewable energy supply.*

- as if that means something.

What coal? What role? Well, who cares. You only asked for a story, so that's all you got. Also:

> *Scope 3 emissions will also be reduced through investigation in low emission technologies, such as carbon capture and sequestration (CCS) enable blue ammonia/ hydrogen and electricity export.*

What investigation? When? Where? And most confusingly, how does mere investigation reduce emissions? I'd hate to be the one tasked to connect those dots. But I won't be: no one will be. It's a vibe thing. These are merely the valuable platitudes demanded by NT policy.

Tamboran's own corporate Climate Policy, also unreferenced by the Draft, commits to:

> *Promote the use of new technologies and renewable energy*

however their

> *ongoing commitment to invest in ... renewable energy sources*

is not evident in the Draft.

Tamboran could at least consider the alternative of solar vs diesel to power enhanced evaporation

Not just actions, also proposed monitoring is vastly inadequate for what is a major risk and highly controversial feature of this new industrial process.

The Draft only addresses monitoring emissions at infrastructure (flares, vents and leaks) and of these, only leaks require a response. 6 monthly leak detection of surface infrastructure is grossly inadequate. The response for minor leaks has no escalation / contingency: this could result in 5.30 months of unaddressed major leak.

Instead, Tamboran should implement as standard continuous monitoring of infrastructure. Point based instruments can effortlessly implement continuous methane monitoring with accurate, validated measurements at scale. Events from this monitoring can gather data on trends, trigger investigations on incidents and shore up estimates.

The EMP notes that

> *In addition to monitoring emissions from drilling, stimulation and well testing activities, baseline assessments have been completed by CSIRO in the vicinity of the lease pad*

But to what end? The Draft offers no detail of further landscape measurements, only infrastructure. But fugitive emissions are not limited to infrastructure.

The SREBA describes:

> *natural surface emissions of greenhouse gases from Beetaloo Sub-basin formations.*

Tamboran's activities may exacerbate these existing natural GHG sources, or open new ones.

The SREBA identified options for regional surveys, mobile and static, combining *"optical gas analysers ... to continuously measure ambient methane concentrations"*, and *"flux chambers to measure the flux from possible geologic seeps"* – yet the Draft is silent on landscape monitoring.

GISERA have set a standard, deploying ground based stations for continuous monitoring of atmospheric greenhouse gas concentrations in the Surat Basin to estimate fluxes (primarily methane) from the region. Tamboran should pursue best-in-class practice for monitoring landscape-wide emissions associated with these Beetaloo leases. Exploration is by definition a more experimental industrial phase. It is therefore highly appropriate that Tamboran should be more curious about any impact their activities may have on landscape-wide fugitive emissions.

Other notes

Clearing:

We are given an unhelpful description of clearing as

> *0.019% of the combined surface area*

of the EP leases. Obviously a circle that size would have far less impact than the proposed activities will present.

The proponent should report perimeter, to provide a meaningful measurement.

We are assured

> *most areas will naturally regenerate following rehabilitation following the wet season,*

with no reference to contingency, nor revegetation of those areas not expected to naturally bounce back.

The proponent should describe alternative measures for revegetation, or at least estimate the anticipated scope of un-rehabilitated impact.

Stormwater:

The management of stormwater is inadequately defined. Stormwater features in neither the process water balance nor the wastewater balance. Capacity of stormwater basins should be reported.

Seismic:

We are given:

> *If the use of dynamite is not feasible, vibroseis trucks will be used for the seismic source.*

The proponent should provide an estimate for how many trucks may be used, at how many sites

Groundwater:

The list of sensitive receptors should not ignore groundwater. The draft provides no monitoring for regional groundwater beyond the well-head, and the only control action is well casing and cementing.

The proponent should monitor for and pursue water quality and draw down standards elsewhere on the leases.

Stygofauna:

The Pepper inquiry deferred concerns about impact on Groundwater Dependent Ecosystems to the regional SREBA. Along the way, discoveries were made regarding the presence of stygofauna in the Basin, which both represent a sensitive receptor, and illustrate the interconnected nature of regional reservoirs.

The Beetaloo SREBA did not provide any further certainty about GDE impacts, which were classified undetermined. Yet the Draft appears to reclassify these risks as low, without any further research. Absence of evidence is insufficient grounds to shirk further monitoring.

Threatened fauna:

The decision that

> *During the dry season, flowback will be treated in open treatment tanks to reduce the wastewater volume as much as possible.*

is at odds with exploration of the inquiry into the likely impact on local fauna, which recommended:

> *that enclosed tanks be used to hold wastewater in preference to open ponds (Recommendation 7.12), which would prevent access by wildlife.*

- without any equivocation about evaporation.

This is widely recognised by participants as an unmet recommendation.

The proposed objective:

> *EC-2 – EC-3: <7 individual fauna deaths per week for 2 consecutive weeks caused by flowback water storage*

is alarming. A perverse reading could see this as pursuing unbounded killings by alternate weeks. Perhaps by covering the evaporation ponds every other week. Disgust at abandonment of recommendation 7.12 aside, Tamboran could at least arrive at a less objectionable schedule.

Waste water management:

We are informed that

> *Scaling constraint posed by wastewater restricted the use of conventional water treatment*

and

> *flowback may be reused in the stimulation make up fluid where technically feasible*

but the Wastewater Management Plan tells us that

> *Drilling, completion, suspension and kill fluids*

will be

Transferred to flowback storage facilities

The claim

salinity and scaling constrain the use of conventional water treatment.

seems inconsistent with other NT resources activities.

The proponent should explore potential benefits of quarantining the high-volume production water waste stream from this smaller volume of wet wastes (up to 1ML/well) with higher salinity / EC. This could help maximise compatibility of stored water for reuse, and facilitate alternative management options. The smaller volume of higher salinity waste may then be amenable to conventional treatment. Tamboran could reassess the viability of extending water treatment to the entire stock of waste water.

Erratum

APPENDIX G Wastewater Management Plan on p11 details

Drilling, completion, suspension and kill fluids

as

KCl or NaCl based fluids with a TDS >50,000 us / cm

but TDS is Total Disolved Solids, which are measured as grams per litre. This probably refers to electro-conductivity, which as described in *Appendix J Water Monitoring Suites* is measured in siemens per metre

References

as described.

Contact

Justin Tutty
25 Kapalga St, Tiwi
justin@darwin.email

[redacted]

From: Climate Action Darwin <climateactiondarwin@gmail.com>
Sent: Tuesday, 9 January 2024 11:27 PM
To: tamboran DEPWS
Subject: Climate Action Darwin response to: Tamboran Resources Ltd Beetaloo Basin Shenandoah South Exploration & Appraisal Program Environment Management Plan (TAM1-1) EP 117 and EP 98
Attachments: CAD response to Tamboran Resources Ltd Beetaloo Basin Shenandoah South Exploration & Appraisal Program Environment Management Plan (TAM1-1) EP 117 and EP 98.pdf

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Good morning to the Director Petroleum Operations,

thank-you for receiving the Climate Action Darwin response to:
Tamboran Resources Ltd Beetaloo Basin Shenandoah South Exploration & Appraisal Program Environment Management Plan (TAM1-1) EP 117 and EP 98.

Please find it attached.

Warmest regards

Grusha
for

--

Climate Action Darwin

www.climateactiondarwin.org.au

Facebook: climateactiondarwin

On Tue, Jan 9, 2024 at 4:11 PM tamboran DEPWS <tamboran.DEPWS@nt.gov.au> wrote:

> Dear Grusha
>
> Thank you for your enquiry.

The Minister is bound to only consider comments provided during the 28 day public comment period.

In this instance, the public comment period commenced at 8:30 am on 12 December, and finished at 8:30 am 9 January 2023. The 28 day public comment has been achieved.

It is acknowledged the auto-reply indicated submissions close at midnight 9 January 2024, and as such submissions may be made to Tam1.ep98+117@nt.gov.au until midnight tonight.

I trust this assists.

Director Petroleum Operations

Petroleum Operations / Environment Division

Department of Environment, Parks and Water Security

Northern Territory Government

Floor 1, Arnhemica House, 16 Parap Road, Parap

PO Box 3675, Darwin, NT 0801

NORTHERN TERRITORY GOVERNMENT

Stay up to date and connect with Environment, Parks and Water Security

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I pay my respect to the Larrakia peoples, the Traditional Owners of this Country both past and present

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From: Climate Action Darwin <climateactiondarwin@gmail.com>
Sent: Tuesday, 9 January 2024 2:06 PM
To: tamboran DEPWS <tamboran.DEPWS@nt.gov.au>
Subject: Is a late submission acceptable?

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good afternoon,

We are hoping you will accept our Climate Action Darwin submission regarding this proposed project tomorrow.

Could you please let us know if that is acceptable?

many thanks

warmest regards

Grusha Leeman

for

--

Climate Action Darwin

www.climateactiondarwin.org.au

Facebook: climateactiondarwin

Climate Action Darwin response to:

Tamboran Resources Ltd Beetaloo Basin Shenandoah South Exploration & Appraisal Program

Environment Management Plan (TAM1-1) EP 117 and EP 98

January 2024

Thank-you for taking the views of Climate Action Darwin (CAD) into consideration.

Established in 2009, CAD is a 600-strong community group. It is our moral obligation to current and future generations, and other lifeforms to prevent and reverse climate change. We do this by supporting individuals to take action, advocating for a transition to a zero carbon economy, and influencing decision-makers.

As this community assessment has been thrust on us without warning over the holiday period, it would be beneficial for there to be capacity for fuller consultation by extending the 28 days notice. Diminishing public scrutiny is not in the best interest of good environmental management. Indeed if *"The department is committed to ensuring that as many Territorians as possible are aware of, and have an opportunity to comment on, these EMPs"* then we might also expect them to be mentioned on their social media posts.

Although CAD recognises that there are ample reasons to oppose all of the activities planned by Tamboran, here we focus on their severe impacts to our one and only livable climate. It is already seriously polluted and has no capacity for even more burdens. Indeed we need to be commencing a drawdown program and cease inventing new reasons to continue destroying our systems for life.

methane gas is too potent to release

Mostly made up of methane, fracked gas is a harmful fossil fuel[1] and, as the second most significant greenhouse gas after carbon dioxide, is a key driver of climate change. Once emitted, methane stays in the atmosphere for about nine years – a far shorter period than carbon dioxide. However its global warming potential is 86 times higher than carbon dioxide when averaged over 20 years and 28 times higher over 100 years[2].

[1] https://www.climatecouncil.org.au/resources/future-of-gas-is-small-and-dwindling/
[2] Emissions of methane – a greenhouse gas far more potent than carbon dioxide – are rising dangerously - CSIRO

The levels of methane in the atmosphere are increasing steadily[3] and are around two-and-a-half times greater than pre-industrial levels, contributing significantly to climate change.

As methane is much more potent at warming the atmosphere, we must be particularly cautious about releasing it.

It's important to recognise the gas industry dupes people by calling their climate pollutant "natural" gas, and that's the case repetitively in this draft EMP.

Although we keep getting told that gas is good, releasing methane is not good for the climate:

- Gas has contributed to the largest increase in global fossil CO_2 emissions in recent years.[4]
- Five times more methane is being leaked from oil and gas production than is being reported.[5]
- Methane emissions from the energy sector are 70% higher than official figures.[6]
- Methane gas use may affect climate as much as coal does if methane leaks persist.[7]
- Increasing investments in methane gas carries a long-term risk of delaying the clean energy transition further.[8]

Recommendation: Reconsider allowing any exploration or mining of methane.

deceptive greenhouse gas accounting

In this EMP there are highly concerning attempts to conceal the real magnitude of the anticipated greenhouse gas emissions though evasive accounting.

The maximum total emissions for Tamboran's current predicted activities in Table 25 can be added to be 421,665t CO_2e. Then in Table 26: Estimated cumualtive (sic) greenhosue (sic) gas emissions, offsets and residual emission levels are added but the numbers for the first two years are a little different from the previous table, though the outcome is similar: 421,663 t CO_2e. The discrepancies between the two tables create confusion rather than trust.

Tamboran then immediately compares their potential emissions to those of the NT and Australia's totals, offering the reader a diminished understanding of their climate polluting impacts.

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[3] Methane and climate change – Methane Tracker 2021 – Analysis - IEA
[4] https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf
[5] UK Substantially Underestimates its Methane Emissions from Oil and Gas Production – and Many Other Countries Probably Do Too | Center for Policy Research on Energy and the Environment (C-PREE)
[6] Methane emissions from the energy sector are 70% higher than official figures - News - IEA
[7] Natural gas use may affect climate as much as coal does if methane leaks persist | S&P Global Market Intelligence
[8] The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? - ScienceDirect

On Table 24: Greenhouse gas calculation for the proposed activities, there seems no accounting for inputs to the project, the sourcing of all the materials and transport and other needs of the workers, these also constitute impacts to the climate pollution that should be tallied. Further, there would have to be greenhouse gas emissions released in the rehabilitation phase, even if it goes for only six years. Bunds on wells may well last 10 years, but then who stops the leaks?

Astoundingly, instead of accounting for their own expected pollution, the draft EMP details their "*climate benefits.*" The tiresome repetition of claims that we need this toxic methane to replace coal only works if
(1) we are indeed halting coal - instead we are *still* adding to it, and
(2) if it were possible to mine, process and transport it cleanly.

Independent analysis of the industry[9] shows gas may indeed be the dirtier fuel source.
"If 3% to 4% of natural gas produced at oil and gas wells leaks into the atmosphere, power produced by natural gas plants is on par with coal plants in terms of the overall climate impact. If upstream emissions exceed that percentage, natural gas would be more harmful than coal in the short term."

If future *Beetaloo shale gas development will be net zero scope 1 and 2 emissions*, why is there little effort made to limit the emissions for this EMP? The world's best practice emission reduction technologies could be invested in from the get go. Instead there's a twentieth century reliance on diesel.

The point of this exploration is in the hope to sell methane gas, and downplaying the scope 3 emissions when they could comprise 80 percent of their emissions,[10] is deceptive. Aiming to gain regulatory lenience for the possible future 'beneficial use' of gas, Tamboran seems to be attempting to dismiss their emissions, without offering any assessable detail.

But if Tamboran is expecting to frack and flare three wells in FY25, the year with the greatest emissions (190,554 tCO_2 e) for the Shenandoah South E&A Program EMP, and there is expected to be a total of 15 wells, why are the greenhouse gas emissions for the other years so much less? For FY24 =24,162 tCO_2 e, FY26= 98,115 tCO_2 e and FY27=86,395 tCO_2 e (Table 25). The total annual emissions for the four years can be added up to be 399,226t CO_2 e. This is curiously just below 4x the Safeguards threshold.

It appears that the drop in subsequent years is based on their unassessed plan to onsell appraisal methane. Tamboran has expressed a hope they will be allowed to sell before they get a production licence, but surely as this is not approved, this initial EMP should tally the whole emissions. According to

[9] Natural gas use may affect climate as much as coal does if methane leaks persist | S&P Global Market Intelligence
[10] Methane: Can COP28 advance reduction efforts, international cooperation on the greenhouse gas?

Table 25, *"the activities include all those required to construct, drill, stimulate and well test the E&A wells over the FY 2024-2027 period*". It doesn't explicitly account for this big difference:

> *"The provision of a viable alternative to flaring allows Tamboran a future strategy to reduce its scope 1 emissions through a future "flare avoidance program". This is anticipated to reduce scope 1 emissions beyond FY25 (i.e. FY 26 , 27 and beyond) by approximately 80%, and is reflected in the project's current emissions forecast. Flaring will still be required in FY 24 and FY 25, to obtain enough information to underpin the capital investment to justify temporary appraisal sale infrastructure ($10's of millions). In FY 26 and 27, flaring is anticipated to be restricted to the initial well clean up period (subject to beneficial use of gas approval)."* (page 120)

They expect approval before committing to management of their biggest impact: *"Tamboran will seek the necessary approval (i.e. through the revision of this EMP or submission of a new EMP) and prioritise beneficial usage of gas to reduce scope 1 emissions."*

Recommendation: the EMP must not be finalised until Tamboran either: better define their on-selling plans and submit the detail for assessment, or otherwise account for this, their largest emissions burden. This assessment process must not reward their clumsy attempt at sleight of hand.

end methane emissions from venting

Although there is mention in the draft EMP regarding reducing emissions, there remains a warning that the emissions intensity per well is likely to be significantly higher than that expected during production.

It is about time there is effort made to avoid venting: *"Venting to be eliminated as far as reasonably practicable."*

However, there are expected to be *Fugitive emissions for completion (venting) with 2 completion days anticipated per well.* The reference looks outdated:

> "Table 5-23 Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry; American Petroleum Institute (API), 2009 NGERS completion factor of 25.9 tonnes of methane per day multiple by NGERS Global Warming Potential (GWP) of 28 tCO2 -e/tCH 4."

Surely 15 years later and much more understanding of the climate dangers of methane there can be improved methodologies! What efforts have been made to actually eliminate venting?

The IEA[11] advises that:

"Stopping all non-emergency flaring and venting is the single most impactful measure countries can take to reduce methane emissions from oil and gas operations."

Let's ensure that venting is not a planned activity, as even 30 days of venting potent methane is too much of a burden. If we were to be aware that most of us will be alive whilst this methane is in the atmosphere, then using that more realistic Global Warming Potential of 86, the planned vented methane is 25.9 tonnes per day by 15 wells by 2 days completion by 86 GWP giving **66,822 t CO_2-e**. This is nearly three times the reported 23,206t CO_2-e.

Recommendation: Disallow all non-emergency venting.

stop methane emissions from flaring

Tamboran says it hopes to reach the widely questionable flare tip combustion efficiency of 98%, but as that is merely aspirational it may be more honest if there was expectation that the efficiency would be closer to that actually observed in the USA: 91%. *"This means that nearly five times more methane is released to the atmosphere from flares than presently assumed, which, if mitigated, would be equivalent to removing ~2.9 million cars from the road."*[12]

Carbon intensive and noxious flaring remains a planned Tamboran activity. *"Approximately 90% of the anticipated emissions are associated with flaring."*

As a part of grasping for a livable climate we must swiftly eliminate flaring across the globe as well as venting. In the IEA *"Net Zero Emissions by 2050 (NZE) Scenario*[13]*, all non-emergency flaring is eliminated globally by 2030, resulting in a 95% reduction in flared volumes and avoiding 365 Mt CO_2-eq."*

That means we will need to cut flaring levels by over half by 2025 to get to zero by 2030.[14] So just doing part of our obligations as citizens of this climate safe planet, we cannot permit *any* new plans for flaring.

Recommendation: Disallow all non-emergency flaring.

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[11] https://www.iea.org/reports/global-methane-tracker-2023/overview
[12] https://graham.umich.edu/media/files/F3UEL-Fugitive-Emissions-from-Flaring.pdf
[13] https://www.iea.org/energy-system/fossil-fuels/gas-flaring
[14] Direct CO2 combustion emissions from flaring and flaring intensity in the Net Zero Scenario, 2010-2030 – Charts – Data & Statistics - IEA

stop gas emissions from leaks

Methane leaks from the oil and gas sector, also known as fugitive emissions, constitute a significant environmental concern. The conservative IPCC's Sixth Assessment Report estimates that these leaks accounted for 5.8% of greenhouse gas emissions in 2019. A 2023 study published in Environmental Research Letters by Brown University's Deborah Gordon reveals that even leakage rates as low as 0.2 per cent can render natural gas as harmful to the climate as coal[15]

The IEA estimated that the global natural gas sector was responsible for nearly 36.7 million tonnes of methane emissions in 2022[16]. Although it is known that *"in the oil and gas sector, emissions can be reduced by over 75% by implementing well-known measures such as leak detection and repair programmes and upgrading leaky equipment",* the trend is merely flattening.

"Where a gas gathering line is used, pressure monitoring and 6 monthly pipeline inspections will be undertaken to detect pipeline leakage as described in the methane emission management plan."

With the gas industry having such a polluting history, attempting to have a half yearly roster of monitoring for leaks is appalling. Another aspect of the IEA's Net Zero Emissions by 2050 Scenario[17], where methane emissions from fossil fuel operations need to fall by around 75% by 2030, is the universal adoption of monthly or continuous leak detection and repair programmes. Best practice is continuous monitoring, so that's what we need to see. Leaks are responsible for too much climate damage already.

Recommendation: the EMP should not be finalised until Tamboran commits to no less than continuous monitoring of all infrastructure points.

fugitive emissions need to be monitored

Already in the Beetaloo, there is methane bubbling from hot springs.[18] Add the impacts of fracking, the complexities of the geology, and we may have endless fugitive emissions. Boundless possible indeed. Just the Velkerri B layer of the Beetaloo Basin has been estimated to contain 500 Trillion cubic feet of gas. Then there are the other known gas bearing geological layers. The NT Government advises[19] this massive resource is "*equivalent to more than a thousand times the current annual domestic consumption in*

[15] Methane: Can COP28 advance reduction efforts, international cooperation on the greenhouse gas?
[16] https://www.iea.org/reports/global-methane-tracker-2023/overview
[17] Net Zero Emissions by 2050 Scenario (NZE) – Global Energy and Climate Model – Analysis - IEA
[18] Methane bubbles in groundwater cast doubts over Beetaloo basin fracking approval, scientists say | Northern Territory | The Guardian
[19] https://territorygas.nt.gov.au/projects/beetaloo-sub-basin

Australia." But it is also potentially our climatic nightmare. There appears to be no plans to monitor the district for landscape emissions.

Recommendation: the EMP should not be finalised until Tamboran commits to a credible monitoring plan for landscape emissions.

Pepper recommendations still unmet

Following the NT government's abandonment of the fracking moratorium, David Ritchie who was tasked with overseeing the NT government's implementation of the Pepper Inquiry stated:[20]

> *"My report makes it very clear ... that [with recommendation] 9.8, we've still got Scope 2 emissions that have not been accounted for. The inquiry found that the release of that quantity of gas, that 26-odd million tonnes, is an unacceptable risk. That's why 9.8 exists."*

An extraordinary Freedom of Information request revealed that NT Government abandoned the policy to meet this key climate recommendation from the Pepper scientific inquiry into fracking[21] instead allowing industry to find the best ways to decarbonise their businesses, or not. A Territory-level policy to restrict direct emissions from gas production to net zero was never implemented. Instead, the NT government requires onshore gas companies to submit a greenhouse gas abatement plan (GGAP) to the NT environment minister before commencing production and to demonstrate operations would be net zero by 2050 at a minimum. The GGAP should be included as part of this EMP, given that Tamboran plans to on-sell appraisal gas.

The federal Parliament last year legislated a requirement for direct emissions (scope 1) from new gas fields to be net zero. As it does not capture scope 2 emissions, it is insufficient to meet the fracking inquiry's most important climate recommendation in its entirety – the energy used by gas companies – or domestic scope 3 emissions from when the gas is sold and burnt.

So we still await the fulfilment of the promise that there should be no net increase in greenhouse gases in Australia before fracking can proceed, as required by Pepper Review Recommendation 9.8.

Recommendation: No gas industry works be approved until all the Pepper commitments are completed in full.

Recommendation: The EMP should not be finalised until we can assess the greenhouse gas abatement plan.

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[20] https://www.abc.net.au/news/2023-05-04/nt-beetaloo-analysts-question-pepper-inquiry-progress/102299456

[21] Net zero policy for new gas projects abandoned after industry objected | Australia news | The Guardian

Beetaloo is a climate bomb

How can a fossil fuel basin that is bigger than any current gas project on Western Australia's North-West Shelf, containing "*technically recoverable fossil gas resources equivalent to 60 times*[22] *Australia's current consumption"* be carbon neutral?

It's been estimated[22] that a whopping 1.2 billion tonnes of greenhouse gas emissions would be emitted over 25 years to 2050 – a figure 45% higher than in the GISERA/CSIRO report that the NT Government used to give the green light to fracking.

Over the 25-year lifetime of the project, Tamboran's current development plans result in lifecycle greenhouse gas emissions that amount to twice Australia's total 2021 emissions.

We can no longer afford to keep increasing our emissions.

offsets can't save the climate

The Report that the NT Government used to defend the climate impact of giving a green light to fracking, the CSIRO GISERA Report[22], focused on using offsets rather than real mitigation measures. They put the emphasis on offsets, despite findings that offsets are not a viable alternative to cutting emissions. The Report also overestimated the supply of offsets in Australia, by using liberal assumptions for all the offsetting methods under the Emissions Reduction Fund, and assumed a potential supply of offsets sufficient to offset Australia's 2021 emissions in their entirety.

Although it is not possible under the recent Safeguard Mechanism regulations, the CSIRO GISERA report assumed up to 42% of offsets would need to be sourced internationally. They also significantly exaggerated the viability of blue hydrogen and carbon capture and storage.

One tonne of carbon dioxide pumped into the atmosphere by burning methane is not the same as one tonne of carbon stored in the tree trunks of young trees. This is because fossil carbon is not current carbon, it's freshly added to the system which is now unbalanced. To avoid severe climate change we must leave all the fossil methane underground. Offsets are simply an accounting trick and cannot save us.[23] Instead, reliance and overuse of offsets could see even more emissions and even worse climate disaster.

Recommendation: Prioritise avoidance over offsets.

[22] https://ca1-clm.edcdn.com/assets/emissions_impossible.pdf
[23] A tonne of fossil carbon isn't the same as a tonne of new trees: why offsets can't save us

gas can't be stored forever

Carbon Capture and Storage (CCS), when attached to fossil fuel developments, is not a climate solution. [24] We need to end fossil fuel mining to reach net zero. Warming will continue long after emissions reach net zero. For a safe climate, we need to draw down and to do that we must swiftly stop using fossil fuels.

CCS is extremely expensive and cannot deliver zero emissions. The only solution is to leave fossil fuels underground. When paired with gas, CCS is simply an attempt to prolong the life of polluting fossil fuels in our energy system.

If we try to dump the CO_2 under the seabed, there is no way anyone can ensure it will stay there. And it is likely to seep out over time, or in the old pipes along the way. It is not a closed system and there are fissures. Large earthquakes are common in the seabeds north of Australia, and they can crack the rocks holding gas underground. And the high pressure inputs are associated with micro tremors. It is not a safe bet that it will stay down.

Recommendation: Abandon the pretence that Carbon Capture and Storage is feasible.

leave the gas in the ground

Methane is not a transition fuel, instead it is one of the main drivers of climate change. Multiple high level recommendations from sources such as the IPCC, the IEA, and Climate Analytics, all show that for a livable climate there should be no new gas projects.

Avoiding the worst of climate change means abandoning plans for further fossil fuel expansion and going all in on transforming our energy system, including the managed phase-out of existing gas facilities. This means for a safe place to live we must accept that fossil fuels have got to go, starting with no new gas.

Australia has signed the 2021 Global Methane Pledge (GMP) which aims to collectively reduce global methane emissions by at least 30% from 2020 levels by 2030, a target that could avert over 0.2°C of warming by 2050. Instead of contributing to a global methane emissions rise of 13% by 2030, and decimating the cattle industry, the NT's contribution should be a simple no new gas.

In 2022, the U.N. Secretary-General António Guterres said[25]

> *"We are on a fast track to climate disaster. We need to cut global emissions by 45% this decade. But current climate pledges would mean a 14% increase in emissions, and most major emitters are not taking the steps needed to fulfil even these inadequate promises."*

[24] https://www.climatecouncil.org.au/resources/what-is-carbon-capture-and-storage/
[25] U.N. Report Details 'Fast Track to Climate Disaster'

Let's be leaders for a livable planet, not be part of the problem. This project will contribute to that 14% increase, and so should be denied.

This project is to be assessed under the NT Petroleum Environment Regulations[26]

> The object of the Regulations is to ensure that regulated activities are carried out in a manner:
>
> (a) consistent with the principles of ecologically sustainable development; and
>
> (b) by which the environmental impacts and environmental risks of the activities will be reduced to a level that is: (i) as low as reasonably practicable; and (ii) acceptable

It is clear that the principles of ecologically sustainable development are not met and the environmental risks and impacts are clearly not reduced to a level as low as is reasonably practicable and with a climate bomb being detonated are really not at all acceptable.

This is our 'last chance' decade. The IPCC warns we have almost run out of time. Our window to avoid the worst of climate change is rapidly closing. So the decisions we choose to make now, this year, and over the coming decade will make a world of difference to our health, well being and economic future. We must consider this our last warning.

Recommendation: Deny Tamboran permission to proceed.

Email: climateactiondarwin@gmail.com
Website: climateactiondarwin.org.au
Facebook: Climate Action Darwin

[26] https://legislation.nt.gov.au/en/Legislation/PETROLEUM-ENVIRONMENT-REGULATIONS-2016

From:	Nurrdalinji Contact
To:	tamboran DEPWS
Subject:	Comment on Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98 (EMP)
Date:	Tuesday, 19 December 2023 8:58:13 AM
Attachments:	240109__Nurrdalinji submission Tamboran EMPs 117_98 .docx.pdf

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Please find the attached submission.

Samuel Sandy
Chairperson
Nurrdalinji Native Title Aboriginal Corporation

Nurrdalinji Native Title Aboriginal Corporation
ABN: 32 608 508 769
ICN: 9392

Department of Environment, Parks and Water Security
Petroleum Operations unit
PO Box 3675
Darwin NT 0801

By email: TAM1.EP98+117@nt.gov.au

19 December 2023

Dear Colleagues,

Comment on Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98 (EMP)

Nurrdalinji Native Title Aboriginal Corporation (Nurrdalinji) was established by native title holders of the Beetaloo Sub-basin/Barkly regions, and was registered with the Office of the Registrar of Indigenous Corporations on 9 October 2020. Our name, “Nurrdalinji”, is an Alawa language word meaning “mixed tribe”, which reflects the fact that our membership is drawn from a wide area and several different language groups.

Nurrdalinji is an important vehicle for us to express our concerns and to protect the interests of our members and native title holders in the Beetaloo Sub-basin/ Barkly region. We formed Nurrdalinji to act as a clear and faithful voice for native title holders frustrated by the quality and adequacy of the Northern Land Council’s (NLC) advice and representation of our interests, most recently in relation to fracking on our country.

Our over 60 members have native title and traditional interests across the Beetaloo Sub-basin/ Barkly region, including in the EMP area of EP 117 and EP 98, held by Tamboran Resources.

Please accept the following comments on Tamboran’s EMP made on behalf of Nurrdalinji and its members.

Scope of the EMP

This is an EMP that includes:

- Civil construction of four new exploration and appraisal areas including four new
- well sites and associated infrastructure;
- Civil construction to expand the existing Kyalla 117 N2 site;
- Drilling of up to 15 horizontal exploration and appraisal wells.
- Hydraulic fracture stimulation and well testing of up to 15 horizontal wells at
- four exploration locations;
- Construction of a gathering network connecting exploration sites to allow for the transfer of wastewater (including raw water, flowback, completion and drilling wastewater) and hydrocarbons between four sites;
- Drilling waste and flowback wastewater management on each site, including the transfer between sites including construction and operation of drilling sumps and wastewater storage tanks - total storage of 34 million litres of wastewater on site;

- Seismic acquisition of a total of 77 km of 2D seismic (EP 98 and EP 117);
- The production of more than 400,000 tonnes of greenhouse gas emissions.

Lack of consultation and free, prior and informed consent

Our members affected by this proposal have had no, or extremely limited, engagement with Tamboran or the NLC about its plans to frack our country set out in the EMP.

There is widespread confusion and concern among native title holders about what Tamboran is planning to do, what the risks are and even how Tamboran even obtained consent to frack our country in the first place.

Tamboran claims that *"Detailed community and stakeholder engagement is ongoing and covers Tamboran's activities on a broader level and includes the information required under the Regulations."* (EMP, p.22)

Tamboran has not given native title holders affected by the EMP their "full attention" as it claims. Tamboran appears to not understand that for the purposes of the EMP, the NLC is merely a replaceable representative of native title holders under the *Native Title Act 1993* and should only act in accordance with our informed instructions. Tamboran deals with the NLC without our knowledge or involvement. In doing so, it has failed to meet its own stated standards as well as the requirements of the *Petroleum (Environment) Regulations 2016*.

Working "through" the NLC does not equate with providing information to native title holders. The NLC is not a stakeholder for the purposes of the *Petroleum Act*. The native title holders affected by EPs 117 and 98 are stakeholders, not the NLC. When Tamboran communicates with the NLC it is not talking with affected native title holders, especially when the NLC is not keeping native title holders adequately informed of Tamboran's plans.

The Stakeholder Engagement summary (Appendix N, Part A and B) provides a dearth of information from which it is possible to judge if consultation has been adequate and conducted in compliance with the regulations. It is unclear on what basis Tamboran is claiming that the details of communications between it and the NLC are "confidential and commercial-in-confidence" (Appendix N, Park A) and therefore not available for public scrutiny by us as part of the EMP submission process. "Confidentiality" appears to be used by Tamboran and the NLC to withhold further disclosure of its dealings with the NLC, even from directly impacted native title holders and traditional custodians.

According to the Part A - Stakeholder Engagement Log Summary only two meetings have been held with native title holders. The first, noted as 29 September 2023, was a virtual teleconference, not a face to face meeting. The second, noted as 14-16 December 2022 refers to surveying by two Traditional Owners, one employed by Tamboran and listed as a Tamboran representative. From the stakeholder engagement log it appears that the vast majority of "consultation" was conducted between Tamboran and the NLC over email.

It is therefore difficult to ascertain how native title holders impacted by the proposed works have received adequate information from Tamboran, as claimed, *"of the activity description, location, impacts, potential risk, proposed environmental controls and potential impacts to the stakeholders' rights"* in accordance with section 7 (2) (a) of the Petroleum (Environment) Regulations 2016.

Appendix N, Part B claims information has been provided in accordance with this section of the regulations via 'annual on country meetings, story boards, annual work program communications, face to face meetings, work clearance requests and condition of work reporting'. The problem is that no evidence of this occurring can be gleaned from the Stakeholder Engagement Log Summary. Nor is it the experience of directly affected native

title holders who are members of Nurrdalinji that these events did in fact occur.

If Tamboran's EMP is now approved, it will have been approved without any meaningful consultation with or involvement of affected native title holders.

The Final Report of the 2018 NT Pepper Inquiry notes that the response of Aboriginal people from regional communities "almost universally expressed deep concern about, and strong opposition to, the development of any onshore shale gas industry on their country.[1]" Crucially, the report further notes that this near unanimous opposition is based on the lived experience of communities' dealings with other mining projects. It is these community voices that make up the membership of Nurrdalinji, and whose views we take every opportunity to advocate for, including in this submission.

Gas exploration agreements were signed across communities in the Beetaloo region more than a decade ago, but these decisions were not made in the proper way. In the first case, information about likely impacts of fracking were not well understood. Secondly, any such impacts, such as they were then understood were very poorly communicated to community members. Information was not shared with community members in their own language, little to no advice or support was offered to support communities to consider the nature of fracking proposals, not least any associated risks to water and country.

Traditional Owners have described the "consultation" that happened ahead of signing exploration agreements as processes in which companies said *"you'll get a lot of money, we'll even give you money for your children's education*.[2]" Reflecting on these processes, Nurrdalinji director and Jingili Traditional Owner Janet Gregory has said: *"Nobody ever told us the other side - about what sort of havoc this type of mining could do to our land and our people…I deeply regret that I did not have the information at the time that would have allowed me to tell those old people – before they signed the agreement – to get as much information as they could from different sources. You need knowledge to make the right decision, but it didn't seem to me there was adequate truth telling then - or now…Sadly, this fracking business creates division among families and the biggest division is created by the benefit some believe they're going to reap. But in reality it seems likely the few families that support fracking will get a pittance, in return for their cooperation with the mining companies*.[3]"

No one could credibly claim the above as free, prior or informed consent or, as Tamboran claims in this EMP, that the signing of EPs constitutes "detailed engagement with the host traditional owners through the NLC." (p 198)

Many Nurrdalinji members still insist they have not been properly consulted about the plans that gas companies such as Tamboran Resources have to frack their country at a large scale, or the impacts that such operations would have. Members point to being provided with poor quality information about the impacts and risks of fracking, saying this has compromised their ability to make properly informed decisions prior to signing agreements. Since such agreements were signed, the scale of production that fracking companies are now planning to pursue goes far beyond what was originally presented to members over a decade ago. Our members never properly consented to what is now planned. Indeed, if the

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[1] Northern Territory Government (2018). *Scientific Inquiry into Hydraulic Fracking in the Northern Territory (Final Report), p.266.* Link here.

[2] Gregory, J. (2023, June 20). I feel responsible for my role in fracking agreements signed long ago. But I won't stop fighting to save the Beetaloo basin. *The Guardian.* Link here.

[3] Ibid

scale of fracking operations, and the associated risks had been properly explained to us, we would never have agreed to grant the permits for these companies to enter onto our country in the first place.

The NLC picks and chooses which families and family members it seeks to deal with. For example, in recent times it has begun to establish 'negotiating committees' with a view to cementing appraisal gas and production agreements. It uses a small group of individuals as a way of avoiding holding larger meetings where traditional decision making can occur. In this way, the approach of the NLC and gas companies in promoting their fracking plans and seeking support for them has caused and continues to cause untold divisions within family and community.

Cumulative impacts

To date, neither the Federal government, the Northern Territory government, the NLC or any of the gas companies have genuinely attempted to give native title holders information about the combined or cumulative impacts of fracking proposed for the Beetaloo Sub-basin. The cumulative impacts upon culture, songlines and sacred sites have not been properly assessed. The combined and/or cumulative impacts of fracking proposed in the Beetaloo - particularly for water and sacred sites - demands much more significant information being provided to communities, as well as consultation processes that support their meaningful engagement in good faith decision-making processes.

Tamboran's EMP discusses 'cumulative impacts' but only in relation to its own development and does not take into account other gas companies' plans for the Beetaloo or what the impacts will be if full-production occurs, which the Pepper Inquiry into Fracking estimated may see 6,000 fracking wells across the Beetaloo Basin (Pepper Inquiry Final Report, 98).

Our songlines, dreaming, sacred waterways run right across the Beetaloo Basin. Tribes and country are connected and what happens in one part of the country can impact another area of country far away. Climate change affects us all. Poisoning of country and water affects us all. The impacts are not confined to artificial boundaries drawn up by the government and gas companies.

Tamboran not fit to be a suitable operator, pollution concerns

Despite all the assurances made in this EMP, including the inclusion of a Spill Management Plan (Appendix F), we are worried because Tamboran already faces allegations of being involved in a number of pollution incidents from just one exploration well, Maverick 1. In May 2023, reports of pollution incidents[4] emerged relating to Tamboran's exploration well.

1. The use of more than 300,000L of toxic sump wastewater for dust suppression which resulted in Tamboran being fined[4]. Contractors on Tamboran's work site publicly alleged that they were instructed to continue to spray contaminated drill water at a Tamboran fracking site for dust suppression, exposing workers to the contaminated water in the process. In relation to this incident, the ABC says: "Tamboran reported to the NT government the dam level was lowered by pumping the drilling water from it into a fresh water dam being used to damp down dust on the site and access roads. In the environmental incident report, Tamboran said as soon as a senior manager realised the drill water was being sprayed around that was immediately stopped and the government was informed. Yet [one of the contractors] Frank has contested those claims, telling the ABC he was directed by Tamboran to keep spraying the contaminated water: *"I was told to just continue to wet the roads, wet*

[4] McCutcheon, P. (2023, May 22). Questions raised about the largest fracking project in the Northern Territory. *Australian Broadcasting Corporation.* Link here.

the camp, wet the drill pad, just keep on going until the pump couldn't pick up any more, for about three, four, five days," he said".[5]

2. In November 2022, during big rains, a bund wall around a well-pad failed, resulting in sediment and potentially toxic chemicals from the well-pad being washed off the site, onto a paddock and towards Newcastle Creek, areas of which are registered by the NT's Aboriginal Areas Protection Authority as sacred sites. The purpose of the bund wall around the pad is to confine all spills and storm water to the pad to avoid wash into the surrounding vegetation. Tamboran admitted that the sediment ponds on the pad were not built to accommodate large rain events. Tamboran said, "An inspection of the bund post incident confirmed that the bunds were not sized or constructed to contain the volume of stormwater collected at the failure point."[6]. Tamboran did not notify the NT Government of this further event until February 2023 having made their own decision it was not a problem, so therefore not reportable.

3. The third incident related to an alleged pumping of wastewater containing heavy metals including lead, the drilling fluid additive barium, from its sediment dams out onto paddocks that pastoralists use as breeding paddocks for their livestock. This was the subject of investigation by the NT EPA[7] and so far there has been no public release of any findings.

These events are potentially in breach of Tamboran's own environmental plan, as well as relevant Territory laws, regulations and guidelines. They cast a long shadow over Tamboran's self-assessment of risks from its operations and assurances in the EMP that *"the risks associated with drilling and stimulation activities, often referred to as "high consequence, low likelihood" risks, such as contamination of potable groundwater from onshore gas activities…[attract] a "low" risk rating."* (p 21) The dust suppression incident makes a mockery of Tamboran's claims that, *"All personnel working on site (including visitors) are required to report incidents and near misses that have the potential to, or do, affect the environment….Personnel are also encouraged to submit hazard observation cards to maintain a level of awareness of environmental risk and to ensure a cycle of continual improvement."* (p. 229)

The risks are heightened here, with Tamboran planning to do *"drilling, stimulation, well testing and wastewater storage and treatment operations..over the wet season"* (p 128). The *"robust risk management process"* Tamboran boasts about in its EMP (p 205) has already shown to be wanting. We worry for our country, for the workers, and for the potential environmental impacts of spreading contaminated water on our country. We worry that if Tamboran expands its operations as outlined in this EMP, more of these kinds of incidents will occur.

Water use and contamination

Our concerns about the poisoning of water from activities in this EMP are real, as set out directly above.

Our cultural heritage is connected by the waters that flow under the ground. Those waters hold us, and our stories together. Testimony put by local Aboriginal groups to the NT

[5] Bardon, J. (2023, August 24). Contractors allege Tamboran Resources kept spraying contaminated Beetaloo water for up to five days. *Australian Broadcasting Corporation.* Link here.

[6] See Incident Report here.

[7] McCutchoen, P, (2023, May 22) Questions raised about the largest fracking project in the Northern Territory. *Australian Broadcasting Corporation.* Link here.

Fracking Inquiry, contained in a chapter of its final report, Aboriginal People and their Culture states: *"According to Aboriginal tradition, the aquifers underlying country which may give rise to springs and other naturally occurring water sources can be associated with the travels of ancestral beings and link neighbouring Aboriginal groups, connecting people across the landscape. In the area surrounding the Beetaloo Sub-basin, for example, these connections find expression in the kujika song cycles. Kujika are central to the major ceremonies linking Aboriginal nations and language groups across the region. These songs link people with sites in the landscape and require that a broader group of Traditional Owners and custodians be consulted, not just the group associated with the land directly above the areas proposed for any shale gas wells. The kujika reinforce the concept of mangalalgal, or "the way of the dreaming", which is an explicit imperative to honour and maintain cultural traditions. Traditional Owners have submitted that they are connected with neighbouring Aboriginal groups by "underground culture."*

Water is the key to life and culture in the Beetaloo Sub-Basin, and so any proposal that may involve the use of large amounts of precious water, or that may impact on waters above and below the ground, must be considered very carefully. The proposed works have the capacity to impact our sacred waterway Newcastle Creek which flows right across the Beetaloo to Lake Woods which is particularly significant, listed wetland (p 150).

The EMP notes 5 existing groundwater monitoring bores will come into play with an addition of up to 8 more groundwater monitoring /extraction bores to be installed at each of the three Shenandoah South sites - totalling 24 new bores.

We note recent amendments to ensure the "water trigger" under the federal Environment Protection and Biodiversity Conservation Act 1999 apply to fracking. We are concerned that Tamboran's project may have a significant impact on water resources and believe the issue of water use should be referred to the Federal Minister for approval.

Tamboran notes some wastewater ponds will be open. Recommendation 7.12 of the Pepper Inquiry into Fracking states that 'enclosed tanks must be used to hold all wastewater '. Open wastewater ponds are highly problematic, particularly in the wet season. When the rains come, they can rapidly flood wide areas. However predictable the seasons may have been in the past, they are not as predictable now. Tamboran in its EMP claims no evidence of *"significant interaction of fauna with open wastewater storages".*(p 115) Regardless of when the rains come, large, open ponds containing polluted or poisoned water will be a magnet to the multitudes of birds and animals which inhabit the area, some of which are threatened species as noted in the EMP. Experts analysing the chemicals to be used in those ponds are concerned about the impacts of those chemicals on people, animals and the environment.

The bunds that Tamboran say they will construct and critical spill prevention measures are also no match for the rainy season, as already experienced (see above).

Cultural heritage concerns

The country that Tamboran wants to frack under the EMP is rich in cultural heritage and archaeological sites, as recognised by Tamboran (p 197). Consultation, mapping and sacred sites protection should not be a tick-a-box formality. Yet the work to map and protect sites, so far orchestrated by Tamboran, is limited and disappointing.

Desktop surveys were the main tool. The Cultural Heritage Assessment Report by AECOM (Appendix L) notes that work done *"does not achieve total survey coverage of the Project Areas, and there remains the potential for future additional finds".* (p 9) Indeed, at the time one of the surveys was conducted consultant AECOM admits that *"the final footprints for*

proposed works were yet to be established." (p 19). This makes it difficult to see how possible impacts can genuinely be considered. A limited number of Traditional Owners were involved in the surveys (three) and only two area surveys conducted. One of the Traditional Owners was a Tamboran representative. One pedestrian heritage assessment was conducted without any Traditional Owners present at all (p 19). One sensitive landform was identified during an area survey in Shenandoah North B in the form of a waterhole along the access track. Because of flooding, *"the presence of tangible heritage sites within the identified area was unable to be established.*" (p 37) While the area was identified by a Traditional Owner as *'significant'*, it is unclear how this area will be protected only that *"Traditional Owners requested that impacts to this area be avoided.*" (p 37).

Tamboran notes the activities in the EMP are *"currently under assessment by AAPA"* (p 194). It is unclear if this means an authority certificate/s has been applied for and if one or more have been granted.

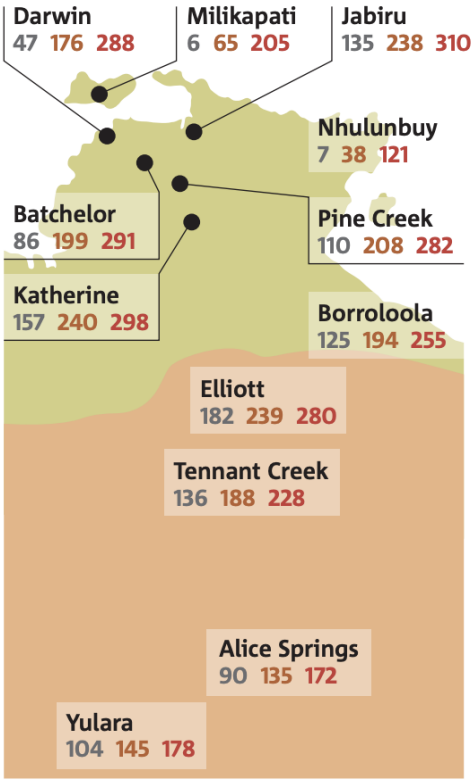
Once again, Tamboran's claims in the EMP to respect cultural heritage are at odds with, and tarnished by, direct experience. In 2022, a subsidiary of Tamboran locked out our then Chair Mr Wilson Jabarda, jungai and proud Gudanji-Wambaya man (now deceased), preventing him from visiting his sacred sites[8]. This represents a serious repudiation of both our cultural authority and our fundamental right to practise our culture.

Climate impacts

For more than a decade, successive governments have been warned[9] that the Territory will be hit with climate impacts harder and sooner than other parts of the country. 2020 CSIRO modelling[10] (see Figure One) makes clear the trajectory of more and more days in excess of 35°C between now and the end of the century.

[8] Cook, J, 24 June 2022, "Gas company locks gate on Tanumbirini Station preventing inspection of sacred Aboriginal sites". Link here.

[9] ABC (2011, November 9). NT to face worst of climate change. *Australian Broadcasting Corporation.* Link here.
[10] Northern Territory Government. (2020, October 9). *Climate Change in the Northern Territory: State of the science and climate change impacts.* Link here.



Annual average number of days over 35°C under a high emissions pathway
Historical 1981–2010 **Mid-century 2036–2065** **End of the century 2075–2104**
FIgure 1. Projected number of annual average number of days over 35°C for the middle (orange) and end of the century (red) compared to the historical (grey) under a high emissions (RCP8.5) pathway. Green shading indicates Monsoonal North projections region, orange is Rangelands. **Source:** CSIRO Report, p.14

These current and future climate impacts amount to a singular public health and social justice challenge for both the Territory and federal governments. Climate change is already making it hotter and harder for us to live on country. As Yanyuwa and Garawa woman and Director of Nurrdalinji, Ms Joni Wilson, who lives with her young family at Lightning Ridge, a tiny outstation located close to Imperial's exploration wells, says: "*We put our feet to this land and it talks to us - it's alive. As a jungayi for my country I have a responsibility to protect and care for it. We used to live off a seasonal calendar, but we notice changes. Country is our supermarket and already we're seeing less and less birds, turkey, fish and goannas and collecting food is becoming harder. Climate change, which will affect everyone, is seeing longer dry seasons and much heavier rains where we live. We don't want fracking, which this report shows will make it hotter and harder for us and future generations to live on country".*

The United Nations[11], the International Intergovernmental Panel on Climate Change,[12] and the International Energy Agency[13] all agree that we can no longer pursue any expansion of

[11] United Nations Secretary General. (2023, June 15). Secretary-General's press conference - on Climate. Link here.
[12] IPCC (2023, March 20). Sixth Assessment Report. Link here.
[13] Harvey, F. (2021, May 18). No new oil, gas or coal development if world is to reach net zero by 2050, says world energy body. Link here.

fossil fuel projects in order to stay within safe limits of climate change. For its part, Australia cannot pursue any more new coal and gas projects if we are to meet our emissions reduction targets.

Nurrdalinji was so concerned about the climate impacts to our people and country from fracking that we commissioned renowned climate scientist Dr Bill Hare at Climate Analytics to prepare a report, *"Unpacking CSIRO GISERA Beetaloo fossil gas emission estimates",* which scrutinises GISERA's report on offsetting Beetaloo emissions, which was widely criticised by climate scientists at the time of its publication[14]. Nurrdalinji sent this report to the Chief Minister and Minister Manison on 2 November 2023. We also submit the Hare report, as part of our EMP submission, for close examination by the Minister.

Dr Hare's report shows Beetaloo and the Middle Arm development project, which will accept Beetaloo fracked gas, would produce emissions of a size that cannot be offset. This is at odds with Tamboran's claims it can offset its emissions. Hare states: "*If it is allowed to proceed, this single [Beetaloo] project could undo all of our efforts to cut emissions. Beetaloo and Middle Arm are a climate bomb. They will produce vast volumes of emissions which cannot be offset. The atmosphere doesn't respond to clever accounting, overly optimistic projections and reliance on offsets – only on how many tonnes of emissions end up there"*[15]*.*

Tamboran estimates total emissions over four years at 400,011 tonnes (345Kt of which comes from flaring). The EMP is unclear and confused when it comes to discussing the impact of Tamboran's project on driving dangerous climate change and the scale and management of emissions. For example, it states "*anticipated peak activity emissions are estimated to peak at 190,838 tCO2-e in the FY 2025*" (p 119) while elsewhere the EMP summary states *"Peak residual emission 83,692 tCO2"* (p 9). Carbon capture and storage is put forward as another plank of Tamboran's plan to manage emissions. CCS not been proved to be a success, with Professor Hare noting in the above report that *"CCS infrastructure has been underwhelming, consistently failing to meet its commitments despite the billions poured into it."* (p.14).

Conclusion

Our concerns about fracking are not new. When the Pepper Inquiry asked us how we feel about fracking some years ago, most of us said we opposed it. None of the information we have received since then has allayed our concerns about fracking, yet it is still being pursued and backed by the NT and Federal governments.

Fracking will further alienate us from spending time on country, and living there. Fracking will make it more difficult to hunt and fish and to enjoy country as precious cultural practices. Fracking will bring trucks, noise and disruption to our communities. It will bring workers from out of town and drive up housing prices and rents. We have not experienced jobs or economic benefits from fracking in the past, or predict we will in future.

Once companies such as Tamboran put their wells across the Beetaloo Basin, where are we going to take our kids fishing and hunting? Where will we go when they damage and pollute the water? What will happen to all our sacred songlines if fracking goes ahead?

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[14] Climate Analytics (2023). Unpacking CSIRO GISERA Beetaloo fossil gas emission estimates. Link here.
[15] Hare, B (2023, October 31). "The Beetaloo gas field is a climate bomb. How did CSIRO modelling make it look otherwise?". Link here.

All of us bear the risks of fracking, yet companies such as Tamboran, as well as the NLC, constantly talk up safeguards, minimise risks and drastically overstate the extent of meaningful consultation with us about their plans.

Tamboran has not met requirements for approval set out in the *Petroleum (Environment) Regulations 2016.* We therefore urge the Northern Territory Government to listen to our people and refuse to approve this EMP.

We also seek your Government's support to change the Top End (Default) PBC arrangements that continue to enable the NLC to lock us into arrangements that we don't want.

Yours sincerely,



Samuel Janama Sandy
Chairman
Nurrdalinji Aboriginal Native Title Corporation

[redacted]

From: Chloe Badcock <Chloe.Badcock@ecnt.org>
Sent: Tuesday, 9 January 2024 4:52 PM
To: tamboran DEPWS; Onshoregas DEPWS
Cc: Kirsty Howey; Alice Nagy
Subject: ECNT Submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP)
Attachments: ECNT Submission - Tamboran Shenandoah EMP.pdf; Shenandoah Attachments_Part1.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good afternoon,

We **attach** Environment Centre NT's submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP) (TAM1-1) under Exploration Permits 117 and 98. We also **attach** a bundle of attachments to the submission in a separate PDF document. We note that this bundle is 1 of 3 and the additional bundles will be sent in an additional emails.

We note that we were unable to submit these documents through the government's portal as the public comment page has been removed before the submission deadline.

Please let us know if you have any questions regarding our submission.

Kind regards,
Chloe Badcock

Freshwater Campaigner

M 0408 162 485 **E** chloe.badcock@ecnt.org **| W** http://www.ecnt.org.au/
GPO Box 2120, Darwin NT 0801 **|** Unit 3/98 Woods Street, Darwin Northern Territory – Australia

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protecting nature | living sustainably | creating a climate for change

To support the Environment Centre please visit www.givenow.com.au/environmentcentrent

We acknowledge the Traditional Owners, The Larrakia people, on whose land we meet, live and work. We pay our respects to their elders past, present and emerging. We acknowledge Australia's First Nations never ceded sovereignty of their lands, seas and waters.

[redacted]

From: Chloe Badcock <Chloe.Badcock@ecnt.org>
Sent: Tuesday, 9 January 2024 4:54 PM
To: tamboran DEPWS; Onshoregas DEPWS
Cc: Kirsty Howey; Alice Nagy
Subject: RE: ECNT Submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP)
Attachments: Shenandoah Attachments_Part2.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Good afternoon,

Further to my previous email, please find attached bundle 2 of attachments to ECNT's submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP) (TAM1-1) under Exploration Permits 117 and 98.

Kind regards,
Chloe Badcock

Chloe Badcock (they/she)
Freshwater Campaigner

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From: Chloe Badcock
Sent: Tuesday, 9 January 2024 4:54 PM
To: 'TAM1.EP98+117@nt.gov.au' <TAM1.EP98+117@nt.gov.au>; 'Onshoregas.depws@nt.gov.au' <Onshoregas.depws@nt.gov.au>
Cc: Kirsty Howey <kirsty.howey@ecnt.org>; Alice Nagy <Alice.Nagy@ecnt.org>
Subject: ECNT Submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP)

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[redacted]

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To: tamboran DEPWS; Onshoregas DEPWS
Cc: Kirsty Howey; Alice Nagy
Subject: RE: ECNT Submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP)
Attachments: Shenandoah Attachments _Part3.pdf; 18. Stockholm Institute, The Production Gap Phasing down or phasing up - Top fossil fuel producers plan even more extraction despite climate promises

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Good afternoon,

Further to my previous email, please find attached bundle 3 and Attachment 19 of attachments to ECNT's submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (EMP) (TAM1-1) under Exploration Permits 117 and 98.

Kind regards,
Chloe Badcock

Freshwater Campaigner

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Cc: Kirsty Howey <kirsty.howey@ecnt.org>; Alice Nagy <Alice.Nagy@ecnt.org>
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NT Department of Environment, Parks and Water Security
Goyder Centre
25 Chung Wah Terrace
Palmerston NT 0830

09/01/2024

By email: TAM1.EP98+117@nt.gov.au

To Whom it May Concern,

Re: SUBMISSION ON THE SHENANDOAH SOUTH E&A PROGRAM EMP

Summary

1. The Environment Centre NT (**ECNT**) is the peak community sector environment organisation in the Northern Territory of Australia, raising awareness amongst community, government, business and industry about environmental issues, holding government to account over environmental governance, and supporting community members to participate in decision-making processes and action.

2. ECNT provides this submission on the Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (**EMP**) (TAM1-1) under Exploration Permit (**EP**) 117 and EP 98 (**Shenandoah EMP**).[1] Tamboran B2 Pty Ltd (**Tamboran**) submitted the Shenandoah EMP for approval to the NT Minister for Environment (**Minister**) on 1 December 2023.[2]

3. The purpose of the Shenandoah EMP is to support Tamboran's development of shale gas within EPs 98 and 117.[3] Tamboran's goal in EPs 98 and 117 is to produce 182 petajoules (**PJ**) per year of natural gas for delivery via pipeline to the East Coast gas market,[4] resulting in approximately 3.5-8 million tonnes of carbon dioxide equivalent (**CO2-e**) per year,[5] and to support development of

[1] Tamboran B2 Pty Ltd (**Tamboran**), *Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98* (**Shenandoah EMP**) Doc #: TB2-HSE-MP-08 (16 Nov. 2023) p. 24.
[2] NT Government, *Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan* (2023).
[3] Shenandoah EMP, p. 24 ("The Shenandoah South Exploration & Appraisal (E&A) program EMP is designed to collect appraisal data to determine the future technical and commercial viability of the underlying shales within EP 98 and 117").
[4] Tamboran, *Assets* ("Tamboran is focused on progressing a proposed pilot development in EP 117/98… scaling up to a >500 TJ per day [.5 PJ/day or approximately 182 PJ/year] development via a new pipeline to the East Coast gas market by the end of 2028").
[5] NT Government, *Scientific Inquiry Into Hydraulic Fracturing In The Northern Territory – Final Report*, (April 2018) (**Pepper Inquiry Report**), p. 228, Table 9.4 (56.3 Mt CO2-e lifecycle emissions for 1240 PJ/year of gas produced for Australian market, 0.045 Mt CO-e per PJ for gas used domestically, and 0.094 Mt CO2-e per PJ for gas for Australian

a liquified natural gas (**LNG**) terminal at the Middle Arm Industrial Hub in Darwin with the capacity to produce 6.6 million tonnes of LNG per annum (**MTPA**).[6] Tamboran's proposed Darwin LNG terminal is planned to expand to 20 MTPA of LNG and result in annual lifecycle emissions of 81 million tonnes of CO2-e, equivalent to nearly 6 times the current total annual emissions of the Northern Territory, or the annual emissions of 12 new coal-fired power stations.[7] During the LNG facility's 20-year lifespan, accounting for a ramp up in production and a tailing off towards end of life, the facility would produce 1.4 billion tonnes of emissions,[8] consuming approximately 25% of Australia's total remaining carbon budget from 2024 to 2050 for limiting global temperatures to 1.5°C.[9]

4. Thus, the Shenandoah EMP is part of a single enterprise aimed at selling shale gas from EPs 98 and 117 for domestic use and export, becoming one of Australia's largest sources of GHG emissions and resulting in significant environmental impacts.

5. ECNT submits that the Shenandoah EMP clearly has the potential to significantly impact the environment as follows:

   i. First, activities covered by this EMP will generate at least a half a million tonnes of carbon dioxide equivalent (**CO2-e**) greenhouse gases (**GHGs**) in only four years, [10] mainly from flaring natural gas at wells that will be stimulated by hydraulic fracture, or fracking.[11] These emissions are likely under-reported, as detailed further below, and thus the actual climate impact of the project is likely even more significant. These emissions must be viewed as part of the cumulative emissions of Tamboran's plans to produce gas from EPs 98 and 117, as described above, that will generate emissions and pose a risk of significant impact on the environment.

   ii. Second, activities under this EMP will require the extraction of 1.5 billion litres of freshwater, and .[12] Water extraction of this scale can significantly impact freshwater ecosystems, and the people and species who rely on them. Large-scale water extraction and the use of fracking fluids can also significantly impact both groundwater and surface water quality.

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and international markets). *See also*, The Australia Institute, *Emissions from the Tamboran NT LNG facility* (Aug. 2023) (.019 Mt of CO2-e per petajoule of gas developed from the Beetaloo Basin).

[6] Tamboran, *Assets* (development in EP 117/98 is for the purpose of supporting a "proposed 6.6 MTPA Northern Territory LNG (NTLNG) development at Middle Arm Sustainable Development Precinct in Darwin").

[7] Based on the latest data available, the Northern Territory's annual emissions for the year to December 2021 were estimated to be 14.1 Mt CO2e: Department of Climate Change, Energy, the Environment and Water, Australian Government, *Australia's National Greenhouse Accounts: Emissions by State and Territory* (2023).

[8] The Australia Institute, *Emissions from the Tamboran NT LNG facility* (Aug. 2023) p. 4.

[9] Based on Australia's upper-end trajectory towards 1.5°C under the fair share methodology, the total national carbon budget from 2024 to 2050 (excluding Land Use, Land Use Change and Forestry) is 5,543.6 Mt of CO2e: Climate Action Tracker, *Australia: Data Download* (28 March 2022).

[10] Shenandoah EMP, p. 120, Table 23 (400,011 tCO2-e for four years prior to offsets).

[11] Shenandoah EMP, p. 119 ("Approximately 90% of the anticipated emissions are associated with flaring").

[12] Shenandoah EMP, p. 103 (375 ML/year of water, multiplied by four years of operations is 1,500 ML).

iii. Third, the activities under this EMP could have a significant impact on cultural values, which must be comprehensively assessed. The independent Scientific Inquiry Into Hydraulic Fracturing In The Northern Territory (**Pepper Inquiry**) identified a number of different ways fracking could impact the land and culture of Traditional Owners and there are a multitude of examples of Aboriginal communities expressing concerns about the impact of fracking. Notably, the SREBA commented that "There were two very strong messages emerging... that people do not trust the onshore gas industry to 'do the right thing' by the people of the Beetaloo region or the environment, and they also have little trust in governments to regulate the industry in a way that will prevent accidents or malpractice from happening"[13]

6. Accordingly, section 50(1) of the *Environment Protection Act* applies to this action, and you should:
   i. refer the Shenandoah EMP to the NTEPA under section 50(2)(c) of the *Environment Protection* Act; and
   ii. refuse to consider the application until the Shenandoah EMP is referred to the NTEPA and a decision is made on the referral, pursuant to s50(2)(a) of that legislation.

7. In addition, this project should be referred for assessment under the *Environment Protection Biodiversity Conservation Act 1999* as it has the potential to cause significant impacts to matters of national environmental significance, including threatened species and water resources.

8. Alternatively, the Minister should also reject the EMP because it does not comply with the *Petroleum (Environment) Regulations 2016* (NT) for the following reasons:
   1. First, Tamboran has not managed its environmental risks to be as low as reasonably practicable (**ALARP**) nor acceptable;
   2. Second, the EMP is not appropriate for the nature and scale of the regulated activity;
   3. The EMP does not contain the information required within Schedule 1; and
   4. The EMP does not include an Authority Certificate Certificate issued by the Aboriginal Areas Protection Authority, which is a pre-condition to approval.

9. Further, the EMP does not comply with the Onshore Code of Practice, including mandatory requirements related to monitoring of methane and leak classification.

10. This EMP should be rejected because it does not meet requirements under the Commonwealth Safeguard Mechanism in at least two ways. First, the EMP's emissions are likely to be higher than calculated and Tamboran must be able to demonstrate it can secure the carbon credits to offset these emissions to comply with the Safeguard Mechanism. Second, the Shenandoah EMP fails to account for the broad definition of a 'facility' under the Safeguard Mechanism and does not demonstrate that it can offset the emissions from all ancillary activities that are part of its single enterprise to sell gas from EPs 98 and 117.

[13] Dr Katherine Witt, Social, Cultural and Economic Studies of the SREBA for the Beetaloo Sub-basin, (2022) p 29.

Overview of the EMP

11. The Shenandoah EMP is large in its scope because it proposes new activities in addition to assuming responsibility over six additional existing EMPs.[14] New activities include drilling of up to 15 horizontal exploration and appraisal (**E&A**) wells at four exploration locations, including the approved Shenandoah S 2H on the Kyalla 117 N2 location, hydraulic fracture stimulation (**fracking**) at up to 15 E&A wells at four locations, and collection of 77 km of 2D seismic surveys.[15] Activities incorporated into the Shenandoah EMP through existing EMPs that are still active include the following:
    - The drilling, hydraulic fracture stimulation, well testing, suspension, maintenance, monitoring and decommissioning of the Shenandoah South 1H and 2H E&A wells, with stimulation at the 1H occurring as recently as November 2023;[16] and
    - The ongoing appraisal activities and decommissioning of the Beetaloo W-1 well.[17]

12. The proposed hydraulic fracture and well completion activities will be extensive. Fracturing will involve up to 60 stages for each of the fifteen wells fractured and well completions at sixteen wells will last up to 300 days each.[18]

The Shenandoah EMP must be referred to the NT EPA because it has the potential to significantly impact the environment.

13. A project proponent must refer to the NT EPA for assessment a proposed action that has the "potential to have a significant impact on the environment."[19] Impacts include events or circumstances that are either "a direct consequence of the action" or that are "an indirect consequence of the action and the action is a substantial cause of that event or circumstance."[20] An impact may also be "a cumulative impact and may occur over time."[21] A significant impact is defined by having regard to the context and intensity of the impact and the sensitivity, value and quality of the environment impacted on and the duration, magnitude and geographic extent of the impact.[22] If an activity is required to be referred to the NT EPA, including because it has the potential to have a significant impact, the Minister must not approve an EMP until the NT

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[14] Shenandoah EMP, Appendix *A Summary of Approved Regulated Activities at Kyalla EP 117 N2 and Beetaloo W-1 Sites, Incorporated into the Shenandoah South E&A Program EMP EP 117 and EP 98 (TAM1)*, (**Appendix A**) (2023) p. 1 (The following activities arising from the approved regulated activities outlined in the six (6) EMPs below).
[15] Shenandoah EMP, p. 35-6.
[16] Shenandoah EMP, Appendix A, Table A-1. (well was originally approved under Beetaloo Sub-basin Kyalla 117 N2 Multi-well Drilling, Hydraulic Fracturing and Well Testing Program (ORI6-3), approved 22 February 2021 EMP Doc # NT-2050-MP038).
[17] Shenandoah EMP, Appendix A, Table A-1 (well was originally approved under Beetaloo W-1 Exploration Permit (EP) 117 ORI8-2, approved 21 October 2021 EMP Doc #: CDN/ID NT2050-15-MP-039).
[18] Shenandoah EMP, p. 38-39.
[19] *Environment Protection Act 2019* (NT), s. 48.
[20] *Environment Protection Act 2019* (NT), s. 10(1)(b).
[21] *Environment Protection Act 2019* (NT), s. 10(2).
[22] *Environment Protection Act 2019* (NT), s. 11.

EPA has made a relevant determination or approval is otherwise permitted by the *Environment Protection Act 2019* (NT).[23]

14. The Shenandoah EMP should be referred because it has the potential to have a significant impact and the Minister must therefore not approve the EMP.

The EMP's GHG emissions pose a risk of significant impact on the environment, and therefore the EMP should be referred.

15. Scope 1 emissions from the Shenandoah EMP will pose a risk of significant environmental impact and are likely to be much higher than Tamboran calculated.

16. Tamboran's own estimations of Scope 1 emissions from the project demonstrate the risk of significant impact on the environment, considering that they well exceed the Australian government's threshold under the Safeguard Mechanism,[24] explained in more detail below. Tamboran claims its cumulative emissions from this EMP are 400,000 tonnes of CO2-e (**tCO2-e**) and are 421,663 tCO2-e across all of Tamboran's activities from financial years (**FY**) 2024-7.[25] Approximately 90% of the anticipated emissions are associated with flaring.[26] Tamboran claims that its "Emission estimates are conservatively high, assuming that each well is successful (flows hydrocarbons), observed rates are of commercial quantities and activity on each well is completed."[27]

17. To reduce these emissions, Tamboran has two plans. One is to purchase Australian Carbon Credit Units (**ACCUs**) under the Safeguard Mechanism.[28] The second is to use a "flare avoidance program," in which Tamboran anticipates it will reduce its scope 1 emissions beyond FY25 by 80% by capturing the gas for use or third-party sale (beneficial use of gas), which is now permitted pursuant to 2023 reforms to the *Petroleum Act 1984* (NT).[29] With these measures in place, Tamboran claims it will reduce its Scope 1 emissions from this EMP to 177,028 tCO2-e[30] and from all of its cumulative activities to 196,826 tCO2-e.[31]

18. Even with the proposed mitigation, the EMP will emit over 190,000 tCO2-e,[32] nearly doubling the threshold for the "highest greenhouse gas emitting facilities" in the country under the Safeguard Mechanism in at least one year.[33] As such, Tamboran's emissions figures alone indicate the risk of significant impact and warrant referral to the NT EPA.

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[23] *Petroleum (Environment) Regulations 2016* (NT), s. 9(3).
[24] Shenandoah EMP, p. 120, Table 23 (190,838 tonnes of CO2-e in FY 2025).
[25] Shenandoah EMP, p. 126, Table 26.
[26] Shenandoah EMP, p. 119.
[27] Shenandoah EMP, p. 119.
[28] Shenandoah EMP, p. 126.
[29] Shenandoah EMP, p. 119-20.
[30] Shenandoah EMP, p. 120, Table 23.
[31] Shenandoah EMP, p. 127, Table 26.
[32] Shenandoah EMP, p. 120, Table 23 (190,838 tonnes of CO2-e in FY 2025).
[33] Clean Energy Regulator, Australian Government, *The Safeguard Mechanism* (28 July 2023).

19. However, Tamboran has not fairly disclosed to the Minister what the "maximum annual emissions for Tamboran's current predicted activities are anticipated to be."[34] Understanding the risk of significant impact on the environment requires an accurate calculation of a project's potential Scope 1 emissions, including the maximum emissions that could result from the proposed activities. Actual emissions, and therefore the risks of significant harm, are likely to be higher for the following reasons.

20. First, Tamboran's GHG calculations rely on an assumption about how many days well testing will last that is significantly below how long other sections of the EMP assume average and maximum well testing will last. This assumption results in a major change in the total amount of emissions in Tamboran's calculations.

21. Table 24 states that the estimate of flaring emissions was based on "forecasted P50 success case of 4.5 TJ/day per well," and that the emissions calculated from these production rates are based on a series of NGER Determination assumptions.[35] The table also states that the "Anticipated Volume" of gas would be 4,050 TJ total over the life of the project.[36] Basic division shows that these 4,050 TJ of production include the emissions likely for only 56 days of testing per well for 16 wells.

22. The 56 days of testing assumed in the emissions calculation is a significant underestimate of testing duration, based on descriptions of the project activities elsewhere in the EMP. In Table 1, for example, Tamboran states that the project includes "Extended production testing of 16 wells" with average well test duration "anticipated to be less than 90 days, with a maximum of 300 days."[37] Emissions from 16 wells producing 4.5 TJ/day tested for 90 days would lead to 6,480 TJ of gas that would need to be flared. Again, taking their own assumptions, that would produce some 552,225 tCO2-e from flaring alone. Assuming the rest of the conclusions of Table 24 are correct, emissions from the whole project in this case would be 607,071 tCO2-e – over 50% more emissions than Tamboran had suggested the whole project would produce (400,011 tCO2-e).

23. Referral to the NT EPA is required if a project has the "potential" to have a significant environmental impact; this means that the worst case scenario should be considered. As above, according to Tamboran, testing for a full 300 days across 16 wells is the worst case scenario and should have been reported in Tamboran's table. That would lead to estimated production of 21,600 TJ of gas that would require flaring, generating 1,840,752 tCO2-e. Taking at face value the rest of the conclusions of Table 24, this means that the whole project could emit 1,895,598 tCO2-e. In this case, it is likely that actual emissions are underreported in the EMP in *all* years and therefore the underestimation of the project's environmental impact could be even higher.

24. Second, Tamboran's GHG calculations assume beneficial use will be approved and financially viable by FY 2026, and will reduce emissions in FY 2026 and FY 2027 by 80%, despite

[34] Shenandoah EMP, p. 125.
[35] Shenandoah EMP, p. 123, Table 24.
[36] Shenandoah EMP, p. 123, Table 24.
[37] Shenandoah EMP, p. 7, Table 1.

simultaneously admitting that this beneficial use might not occur.[38]

25. The EMP states that a "future 'flare avoidance program'" is anticipated to "reduce scope 1 emissions beyond FY 25 (i.e. FY 26, 27 and beyond) by approximately 80%, and is reflected in the projects current emissions forecast."[39] By adding back the 80% of emissions atop the emissions the company calculates for FY 2026 and FY 2027 in Table 23, it becomes clear that in the absence of such a program, the project's emissions for FY 2026 and FY 2027 would be 490,575 tCO2-e and 431,980 tCO2-e, respectively.[40] Assuming emissions for FY 2024 and FY 2025 are accurately calculated in Table 23, the total emissions for the project if beneficial use were not permitted would be 1,138,055 tCO2-e.

26. Tamboran admits, however, that the "flare avoidance program" would not be guaranteed in FY 2026 and FY 2027: "Flaring will still be required in FY 24 and FY 25, to obtain enough information to underpin the capital investment to justify temporary appraisal sale infrastructure ($10's of millions). In FY 26 and 27, flaring is anticipated to be restricted to the initial well clean up period (subject to beneficial use of gas approval)."[41] This statement implies that if the results of the initial wells do not draw in the capital investment necessary for this infrastructure prior to FY 26, the company could proceed in FY 26 and FY 27 without the flare avoidance program. Tamboran offers no clarity about the amount of capital investment that would make this infrastructure commercially viable or the process they would use to make this decision. Additionally, as the second sentence makes clear, beneficial use is not yet approved for this project, making the implementation of these actions yet more uncertain.

27. Third, Tamboran understates its GHG emissions relative to overall Northern Territory and Australian emissions by including percentages of these emissions that are grounded in faulty assumptions: underestimates of well testing timelines, beneficial use, and offsetting of emissions. Tamboran states that its activities represent 1.35% of total Northern Territory GHG emissions for 2021, and 0.04% of total Australian emissions of the year to date as of March 2022.[42] If these faulty assumptions are corrected, however, the project's Scope 1 emissions alone would in fact represent somewhere between 8.18% and 13.23% of the Northern Territory's 2021 GHG emissions, and between 0.23% and 0.38% of Australia's total annual emissions to March 2022.[43]

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[38] Shenandoah EMP, p. 120.
[39] Shenandoah EMP, p. 120.
[40] This conclusion is based on assuming that the "EMP anticipated greenhouse gas emissions" provided in Table 23 of the Shenandoah EMP (p. 120) for FY 2026 and FY 2027 are 80% less than they would be with the flare reduction program that Tamboran asserts is reflected in the current emissions forecast.
[41] Shenandoah EMP, p. 120.
[42] Shenandoah EMP, p. 125.
[43] This assumes an actual emissions range of 1,138,055 tCO2-e (which is based on removing the assumptions of beneficial use in FY 2026 and FY 2027 from Table 23: see Shenandoah EMP, p. 120)), and 1,895,598 tCO2-e (which is based on fixing flaring estimates in Table 24 to reflect testing of 300 days: see Shenandoah EMP, p. 123). NT emissions for 2021 of 13.9134 M tCO2-e are reported at: Department of Climate Change, Energy, the Environment and Water, Australian Government, *Australia's National Greenhouse Accounts: Emissions by State and Territory* (2023). Total Australian emissions for the year to March 2022, 487.1 M tCO2-e, are reported at: Department of Climate Change, Energy, the Environment and Water, Australian Government, *National Greenhouse Gas Inventory Quarterly Update: March 2022* (2022).

28. In the absence of certainty about both the viability of the "flare reduction program", and the number of days that the company will be testing the 16 appraisal wells, Tamboran should have to report in its EMP the maximum emissions that the project would produce. The company's assertion that "Emission estimates are conservatively high," is clearly inconsistent with the facts. Additionally, the company should be required to show how they plan to offset the entirety of the nearly 922,555 tCO2-e combined emissions from FY 2026 and FY 2027,[44] which exceed the Safeguard Mechanism trigger several times over in each year.

29. Fourth, the EMP underestimates methane emissions from the project by failing to include important sources of methane emissions in its GHG emissions summary. The EMP references only drill cuttings, wastewater storage, and completions as sources of fossil methane emissions during the production, gathering and flaring of gas.[45] Yet it is well established, including via the Pepper Inquiry, that methane and other components of natural gas leak at every part of the production process, including in workovers, from pneumatic devices and other equipment, during liquids unloading and condensate storage, across gathering networks, and even after a well is closed.[46] Each of these are addressed in turn:

i. Workovers: The EMP states that workovers, a form of well maintenance, will occur on 19 wells.[47] The Pepper Inquiry shows that workovers, completions, and liquids unloading together can account for 25% of total "cradle-to-gate" lifecycle emissions of gas.[48]

ii. Pneumatic devices and other equipment (e.g., separators, dehydrators, meters, etc.): As with all producing wells, the project will rely on pneumatic controllers and other equipment to produce, test, purify (separate), and move the gas and maintain appropriate pressures throughout the production system. Pneumatic controllers are well-recognised to be significant sources of emissions during production and throughout the gas lifecycle.[49] Other equipment, such as separators, dehydrators, and meters, have also been found to contribute greater methane leaks than once appreciated during production.[50] One study found that pneumatic controllers account for 38% of emissions in the oil and gas production segment, and other equipment leaks account for 21%.[51]

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[44] As calculated above, 922,555 tCO2-e would be the total emissions after adding back the 80% of emissions atop the emissions the company calculates for FY 2026 and FY 2027 in Table 23 (490,575 tCO2-e and 431,980 tCO2-e, respectively).

[45] Shenandoah EMP, p. 122-123, Table 24. Camp wastewater methane emissions are not considered here.

[46] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, *Final Report*, (April. 2018) p. 212-215.

[47] Shenandoah EMP, p. 7, Table 1.

[48] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, *Final Report*, (April. 2018) p. 212-215.

[49] David T. Allen et al., *Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers*, 49 *Environ. Sci. Technol*. (2015) 633; Benjamin Luck et al., *Multiday Measurements of Pneumatic Controller Emissions Reveal the Frequency of Abnormal Emissions Behavior at Natural Gas Gathering Stations*, 6 *Environ. Sci. Technol. Lett*. (2019) 348.

[50] Jeffrey S. Rutherford et al., *Closing the methane gap in US oil and natural gas production emissions inventories*, 12:4715 *Nature Communications* (2021).

[51] Ramón A. Alvarez et al. Assessment of methane emissions from the U.S. oil and gas supply chain, 361 *Science* (2018) 6398.

iii. Liquids unloading: Mixtures of water and liquid hydrocarbons ("condensate") can accumulate in wells to slow gas production, at which point clearing of the well is necessary, and these liquids are brought to the surface (known as "unloading").[52] There are several liquids unloading techniques, but all result in significant methane emissions. Underestimates of liquids unloading emissions have been found to be a key discrepancy between standard GHG inventory estimates of methane emissions during production, and actual emissions.[53]

iv. Condensate tank storage: The EMP notes that spills/leaks are a risk from on-site storage and handling of condensate,[54] and that condensate will be "beneficially sold where permissible."[55] However, the EMP fails to provide clarity on whether any of these liquids would be stored on site before being flared, and what would occur with the liquids in the case of sale of gas for beneficial use, including whether gas liquids might be stored and sold as well. Leakage and venting from condensate storage would generate additional GHG emissions: a recent study, for example, found that liquid storage tanks were one of the greatest contributors to the divergence between actual emissions at oil and gas production sites and the standard GHG inventories used to estimate those emissions.[56]

v. Gathering network: The EMP states that a methane gathering system may be used: "Produced hydrocarbons will either be flared onsite or gathered to a centralised flare for management (such as Shenandoah S2)."[57] Such gathering networks are prone to leakage both from the lines themselves, and at compressor stations, and are problematic enough to contribute some 20% of total oil and gas supply chain methane emissions in the U.S..[58] High leakage would be particularly likely where these systems are only checked for leaks every six months, which is given as the standard leak detection interval in the Methane Emissions Management Plan.[59]

vi. Post-closure: Wells frequently continue to leak methane and other GHGs after they are closed, and a recent study found that plugged wells are not necessarily lower emitters than unplugged wells.[60]

30. Given the significant contributions of these processes to methane emissions during gas production, their absence in the GHG assessment indicates that the GHG emissions from the project estimated in the EMP are vastly underestimated. Moreover, the high potency of

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[52] U.S. EPA, *Liquids Unloading*

[53] Stefan Schwietzke et al., *Improved Mechanistic Understanding of Natural Gas Methane Emissions from Spatially Resolved Aircraft Measurements*, 51 *Environ. Sci. Technol*. (2017) 7286; Timothy L. Vaughn et al., Temporal variability largely explains top-down/bottom-up differences in methane emission estimates from a natural gas production region, 115(46) *PNAS* (2018) 1172.

[54] Shenandoah EMP, p. 213, Table 59.

[55] Shenandoah EMP, p. 120.

[56] Jeffrey S. Rutherford et al., *Closing the methane gap in US oil and natural gas production emissions inventories*, 12:4715 *Nature Communications* (2021).

[57] Shenandoah EMP, p. 88.

[58] Ramón A. Alvarez et al. *Assessment of methane emissions from the U.S. oil and gas supply chain*, 361 *Science* (2018) 6398.

[59] Shenandoah EMP, Appendix I, p. 3.

[60] Mary Kang et al., *Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania*, 111 *PNAS* (2014) 18173.

methane as a GHG means that the EMP's assumption that flaring will contribute 90% of the project's total emissions is likely inaccurate.[61]

31. Fifth, Tamboran fails to include all of its activities in its GHG cumulative emissions analysis, leaving out Amungee 2H and Shenandoah South 1H wells, both of which have had GHG-generating activity in FY 2024 and which are under operatorship of Tamboran.[62]

32. In an operational update from June 23, 2023, Tamboran stated that the Amungee 2H well "is currently flowing at a steady rate of 0.83 million cubic feet per day," and that "clean up activity is proposed to be undertaken during the third quarter of 2023," (i.e., first quarter of FY 2024). Tamboran's update suggests GHG-producing activities continued into the fourth quarter of 2023 or first quarter of FY 2024. Moreover, in an August 2023 (i.e., FY 2024) ASX Announcement, Tamboran stated that "Fluid lab analysis from the A2H well is ongoing with remedial intervention work planned for later this year."[63] It's likely that this remedial work would include some GHG producing activities. Yet this well is not mentioned in the cumulative impacts assessment for FY 2024-FY 2027 for the EMP.

33. It is also unclear whether the EMP includes Shenandoah South 1H in any of its emissions assessments, despite being on one of the well pads that is included in the EMP and having GHG-producing activity throughout FY 2024. For example, the EMP notes in a footnote, "The regulated activities currently being undertaken under the Kyalla multi-well EMP are incorporated into this EMP"[64] and the activities table in the EMP states that the project will include "Extended production testing of 16 wells across 4 sites (including the existing Shenandoah S 1H1)."[65] Yet the Shenandoah South 1H well, part of the Kyalla multi-well EMP, is not included in this Shenandoah EMP's "Indicative schedule of activities" which begins in November 2023,[66] despite activities on the Shenandoah South 1H well have been ongoing throughout FY 2024 to date. Tamboran stated in December, for example, they had stimulated and were preparing for "30-day initial production" testing which would result in significant hydrocarbon flaring.[67] Neither GHG emissions calculations of the core EMP activities nor the cumulative GHG emissions assessment state whether the Shenandoah South 1H emissions are included. We therefore have to assume they are not included and that the estimates given by the company for GHG emissions from the project are underestimates. Moreover, as noted

[61] Shenandoah EMP, p. 119.
[62] Activities included in the GHG cumulative emissions analysis are noted in Table 25 of the Shenandoah EMP, p. 125-126. As noted throughout its ASX reports in FY 2024, "Tamboran (B2) are the operator of EP 76/98/117 and Tamboran is acting as operator on behalf of the joint venture." *See,* e.g., Tamboran Resources, *ASX Announcement: EP 117 Operational Update: SS1H intersects 90-metres of high quality Mid Velkerri B Shale in 'core' Beetaloo Basin*, (August 30 2023).
[63] Tamboran Resources, *ASX Announcement: EP 98/117 Operational Update: H&P rig spuds Shenandoah South 1H and Amungee 2H update*, (01 August 2023).
[64] Shenandoah EMP, p. 48, fn. 15.
[65] Shenandoah EMP, p. 39, Table 9.
[66] Shenandoah EMP, p. 42, Figure 5.
[67] Tamboran Resources, *ASX Announcement: EP 117 Operational Update: Successful completion of SS-1H stimulation program, preparing to commence flow back and IP30 testing*, (07 December 2023).

below in Section IV, this lack of clarity about the process used to assess these impacts also violates Schedule 1 of the Petroleum Regulations.[68]

34. Sixth, a more accurate and complete accounting of cumulative GHG emissions would include activities of pastoral activities, and other industries across the Basin, regardless of ownership and years, as the impacts of these emissions know no financial year or corporate boundaries, and the requirements of a cumulative impacts analysis to include impacts "in or near permit area" does not constrain impacts to a given corporate entity.[69] Thus, emissions from activity on Tanumbirini wells, among other wells and activities, should also be included in the cumulative GHG emissions analysis.[70]

35. Seventh, the EMP uses an outdated global warming potential for methane of 28, which significantly reduces the significance the EMP assigns to the climate of methane emissions across the project. The IPCC AR6 instead states that fossil CH_4 has a GWP of 29.8 over 100 years, and 82.5 over 20 years.[71] The 20-year timeframe is arguably more relevant given the risks of climate tipping points that lead to an acceleration of warming.[72] However, even using the most recent figures for the 100-year GWP of 29.8 makes a significant difference in the total estimated emissions of the project and should be applied to generate a scientifically defensible emissions estimate.

36. Eighth, and finally, the EMP makes assumptions about emissions that are out of step with a growing body of research into oil and gas production emissions, and hydraulic fracturing emissions in particular, that shows that GHG emissions from the activities covered in the EMP are much higher than were previously recognized.[73] For example, the EMP assumes flare efficiencies of 98%, yet recent research has found that these efficiencies are commonly much lower in practice across oil and gas fields, instead hovering around 91%.[74] The accumulation of these underestimates of emissions in the EMP suggests that direct GHG emissions from the project would be much higher, and therefore have the potential to cause a more significant environmental impact.

The Shenandoah EMP is a substantial cause of major direct and indirect climate emissions that would have a significant impact on the environment.

37. The section above shows how the projected Scope 1 emissions from Tamboran's EMP alone have the potential to cause significant environmental harm. Even so, in determining the need

[68] *Petroleum (Environment) Regulations 2016* (NT), Schedule 1, s. 3.
[69] *Petroleum (Environment) Regulations 2016* (NT), Schedule 1, s. 3.
[70] For example, Tamboran Resources, *ASX Announcement: EP 161 Update: Flow test analysis of Tanumbirini wells*, (23 June 2023).
[71] IPCC, *AR6 - Climate Change 2021, The Physical Science Basis - Chapter 7*, (August 2021) 1017.
[72] Timothy M. Lenton et al., *Climate tipping points — too risky to bet against*, 575 (7784) *Nature* (2019) 592.
[73] For example, Ramón A. Alvarez et al, *Assessment of methane emissions from the U.S. oil and gas supply chain* 361 *Science* (2018) 6398.
[74] Genevieve Plant et al., *Inefficient and unlit natural gas flares both emit large quantities of methane* 377 *Science* (2022) 1566.

for EPA referral, the decision-maker should consider also consider the indirect emissions from the project, and whether those emissions could lead to a significant impact on the environment.

38. Indirect emissions of the Shenandoah EMP include those from the production, transport, and export of the gas. As noted above, the purpose of exploring and appraising gas in EPs 98 and 117 is to support development of a 6.6 MTPA LNG export terminal at the Middle Arm Industrial Hub in Darwin.[75] The Shenandoah EMP is a necessary and indispensable component of Tamboran's plans to export gas from EPs 98 and 117 through the LNG terminal at Middle Arm. The Scope 2 and 3 emissions from production, transportation, and exportation of gas from EPs 98 and 117 are thus an indirect consequence of this EMP, and the EMP is a substantial cause of those emissions from those activities.

39. ECNT submits that in assessing the impacts of the Shenandoah EMP, the Minister must therefore have regard to the emissions from ancillary activities to this EMP, including emissions generated by LNG processing for the purpose of gas exports at Tamboran's proposed Middle Arm LNG facility.

40. Total lifecycle emissions from the export of gas from EPs 98 and 117 would undoubtedly have significant impacts on the environment. The Darwin LNG terminal will have annual lifecycle emissions of 81 MTPA of CO2-e, equivalent to the annual emissions of 12 Australian coalfired power stations, and 1.4 billion tonnes of emissions over its lifespan of 20 years.[76] Total emissions from the project would consume approximately 25% of Australia's carbon budget for limiting global temperatures to safer limits, and therefore contribute substantially to climate change. This means that Tamboran's proposed development in Beetaloo would be one of Australia's highest emitting projects and a major contributor to climate harms. Its direct and indirect impacts therefore far exceed the threshold for triggering referral to the EPA on the basis that it could cause significant environmental impacts.

41. A recent report by Bill Hare and Thomas Houlie[77], highlights significant underestimates of potential emissions that would be generated from the Beetaloo Shale gas reserve, with a particular focus on carbon accounting methodologies used in the CSIRO Gas Industry Social and Environmental Research Alliance (GISERA) report[78]. Specifically, in relation to Tamboran Resource's activities Houlie and Hare's report finds that, "Tamboran Resources' plan to develop a 6.6 million tonnes per annum LNG plant at the Australian taxpayer funded Middle Arm gas precinct in the Northern Territory this decade would generate emissions equivalent to 2-3% of Australia's 2021 emissions." This figure will grow in subsequent decades given Tamboran Resource's announced plan to expand capacity to 20 million tonnes per annum, which "would generate emissions equivalent to 10-13% of Australia's 2021 emissions, equivalent to having 30-38 million additional cars on Australia's roads"[79]. As Australia moves to decarbonise Tamboran Resources activities will represent a greater contribution to Australia's overall emissions profile.

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[75] Tamboran, *Assets* (development in EP 117/98 is for the purpose of supporting a "proposed 6.6 MTPA Northern Territory LNG (NTLNG) development at Middle Arm Sustainable Development Precinct in Darwin").
[76] The Australia Institute, *Emissions from the Tamboran NT LNG facility,* (Aug. 2023).
[77] Bill Hare and Thomas Houlie, *Emissions Impossible Report* (2023).
[78] Timothy Baynes et al., CSIRO Gas Industry Social and Environmental Research Alliance (**GISERA**), *Mitigation and Offsets of Australian Life Cycle Greenhouse Gas Emissions of Onshore Shale Gas in the Northern Territory* (2023).
[79] Bill Hare and Thomas Houlie, *Emissions Impossible Report* (2023) pg. 7.

It is estimated that if Australia's emissions were to decline consistently to become net zero by 2050, Tamboran Resource could be responsible for 8-51% of Australia's cumulative emissions from 2024 to 2050. Thus, the significance of Tamboran Resource's cumulative scope of proposed activities and their climate impacts should be considered.

The EMP could have significant impacts on surface water, groundwater and water-dependent ecosystems, and therefore the EMP should be referred.

42. Hydraulic fracturing poses significant risks to surface water and groundwater. Risks to water-based environmental values was a key focus of the Pepper Inquiry, the key risks identified included:
    - Unsustainable groundwater use;
    - The contamination of groundwater with hydraulic fracturing fluids and wastewater from leaky wells or from on-site surface spills; and
    - The effect of any water contamination on surface and/or groundwater dependent ecosystems.[80]

43. The EMP fails to demonstrate that the possible significant impacts to groundwater, surface water and water-dependent ecosystems of the EMP activities would be reduced to an acceptable level. Further, due to the number of risks and potential significant environmental impacts that could result from the EMP activities, the EMP should be referred for assessment under the *Environment Protection Act 2019* on this basis.

Unsustainable groundwater use

44. Tamboran have not yet been granted a licence to extract groundwater for the EMP activities. Tamboran propose to extract up to 375 ML a year - 1.5 billion litres of water over four years – from new and existing Gum Ridge Formation bores. This level of water extraction could have a significant impact on aquifers, surface water, water dependent ecosystems and cultural values. However, the EMP does not sufficiently address the impacts of extracting 1.5 billion litres of water, nor does it explore the water balance, hydrogeology and characterisation of groundwater dependent ecosystems to understand the effects of such extraction. The EMP discussion of groundwater impacts is limited to the ability of the aquifer to return to pre-pump levels and does not address the impact of groundwater extraction on groundwater dependent ecosystems, cultural values and water users.[81] The ability of the aquifer to return to pre-pump levels is based on existing pump tests and groundwater monitoring conducted by the proponent at the site at a much lower extraction rate. This is an insufficient exploration of the potential impacts of groundwater extraction at a significantly higher rate and it does not address the cumulative impacts of the proposed water extraction along with other existing or proposed water extraction in the region.

45. The Gum Ridge Formation is a major aquifer in the Cambrian Limestone Aquifer within the Georgina Basin. ECNT submit that groundwater in the Georgina Basin is already over-allocated, and further extraction could exceed the rate of recharge of the aquifers within the Basin and

[80] Pepper Inquiry Report, p. 16.
[81] Shenandoah EMP, p. 103.

result in unacceptable impacts on groundwater dependencies.) This is because of the episodic nature of recharge of the aquifer, with current data indicating that recharge is considerably lower than the long-term average in most years (and may be negligible under the current climate), except for rare events where rainfall and recharge far exceeds the long-term average. Such periods have likely occurred only three or four times over the past century. We note that there is significant scientific concern regarding the impacts of extraction from the Georgina Basin, particularly at the rates permitted under the recently released Georgina Wiso Water Allocation Plan (**Georgina Wiso WAP**). The Georgina Wiso WAP provides for the extraction of a significant percentage of water from the Georgina and Wiso Basins, which leading water expects have warned "would allow for the unsustainable development of groundwater, with serious potential consequences for groundwater dependent ecosystems, cultural values and water users".[82] In the Georgina and Wiso Basins, current knowledge of the water balance, hydrogeology and groundwater dependent ecosystems are currently not sufficient to fully understand the effects of such extraction.[83] Potential threats of overextraction from the Georgina and Wiso Basins could include:

- Impacts to the region's rivers, flood plains, landscapes and on people who live in the region;
- Water quality risks, such as migration of saline water into fresher parts of the aquifer, and potential aquifer integrity issues associated with concentrated extraction in particular regions;
- As groundwater discharge mechanism(s) from these two basins is poorly understood, there may be additional groundwater dependent ecosystems within or close to the edge of the plan area sustained by Cambrian Limestone Aquifer groundwater (such as springs in the western Wiso Basin, or un-mapped deep rooted vegetation communities). Groundwater dependent ecosystems having reduced access to groundwater for extended periods between recharge events, threatening their survival;
- Drawdown associated with consecutive years (or decades) of aquifer overdraft in the Georgina and Wiso basins would endanger stygofauna communities and reduce cross-basin discharge fluxes within the Cambrian Limestone Aquifer;
- Reduction of spring discharge, river baseflow and water table levels;
- Impacts to flows to springs, rivers and vegetation.[84]

46. A number of these potential impacts are not mentioned in the EMP. The Minister must adopt a precautionary approach in deciding whether to approve the EMP and currently, there is insufficient scientific certainty regarding the water balance, hydrogeology and groundwater dependent ecosystems that could be impacted by the EMP activities. There also exists a threat of serious environmental damage in relation to groundwater dependent ecosystems and culture.

[82] Prof. Matthew Currell and Dr Christopher Ndehedehe, *The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values,* (2022), p. 3.
[83] Prof. Matthew Currell and Dr Christopher Ndehedehe, *The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values,* (2022), p. 3.
[84] Prof. Matthew Currell and Dr Christopher Ndehedehe, *The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values,* (2022), p. 3.

The contamination of groundwater and surface water and impact on dependent ecosystems

47. The impact of contamination on surface and/or groundwater dependent ecosystems is listed as a risk in the EMP, however the EMP concludes that the probability of contamination of surface or groundwater from stimulation fluid or chemicals is so remote that a pathway assessment for water contamination has not been completed.[85] This is clearly inadequate and not in accordance with information required by Schedule 1 of the Regulations.

48. Contamination of groundwater from stimulation fluid, flowback water or chemicals is a significant, well-known risk of hydraulic fracturing. It was a key concern outlined in the Pepper Inquiry issues paper and in the Final Report.[86] The EMP does not include sufficient information regarding the potential for spills, groundwater and surface water contamination. Further, the proponent has not demonstrated that the activity will be carried out in a manner in which the impacts and environmental risks of contamination of surface water, groundwater and water dependent ecosystems as a result of the activity will be reduced to a level that is as low as reasonably practicable and acceptable. We note there exists scientific uncertainty surrounding inter-aquifer connectivity and groundwater quality chemistry in the area and the Minister must take a precautionary approach.

49. In response to Pepper Inquiry recommendations, the NT government commissioned the Regional Environmental and Baseline Assessment (**SREBA**) to address key knowledge gaps regarding hydrogeological connectivity in the Beetaloo Basin. In October 2023, Environment Centre NT engaged independent experts Professor Matthew Currell and Dr Christopher Ndehedehe to review the SREBA. In reviewing the SREBA studies, Currell and Ndehedehe (2023) found that there are critical data and knowledge gaps in Beetaloo Basin water baseline studies, and as a result, there is ongoing uncertainty about the likely impacts of fracking on aquifers, springs and rivers in the NT, including the Mataranka Hot Springs and the Roper River. Importantly, they found that preliminary data indicates areas of substantial connectivity between deep aquifer units and shallow Cambrian Limestone Aquifer and/or springs. [87] Even if separation exists between shale gas layers and aquifers as noted in the EMP, this can change as a result of hydraulic fracturing or associated seismic activity. In September 2022, detectable and correlated concentrations of methane and ethane were detected in the air surrounding Beauty Creek hot springs, when bubbles were identified near the spring vent indicating possible association with Beetaloo Sub-basin gas exploration targets.[88] Currell and Ndehedehe (2023) confirm that substantial additional data and analysis is required to fully assess the extent of connectivity and likely behaviour of deep and shallow aquifers, and impact that the extraction of groundwater could have on interconnectivity and groundwater movement.[89]

50. Rectifying the data/knowledge gaps regarding inter-aquifer connectivity and vertical groundwater quality is vital to assessing the likely impacts of the EMP activities and detecting future impacts and accurately ascertaining their cause and mechanism during operations and

[85] Shenandoah EMP, p. 102.
[86] Pepper Inquiry Report, Chapter 7.
[87] Prof. Matthew Currell and Dr Christopher Ndehedehe, *SREBA Expert Review – Groundwater*, (2023) p 23.
[88] Prof. Matthew Currell and Dr Christopher Ndehedehe, *SREBA Expert Review – Groundwater*, (2023) p 23.
[89] Prof. Matthew Currell and Dr Christopher Ndehedehe, *SREBA Expert Review – Groundwater*, (2023) p 23.

post-well abandonment.[90] The Minister should not approve the EMP without these data/knowledge gaps being filled. ECNT submits that without these data/knowledge gaps being filled, the Minister cannot be satisfied that the EMP contains sufficient science-based information as to the risks of groundwater and surface water contamination, and the impact of any contamination on groundwater dependent ecosystems. Without being aware of the full nature and extent of the risks, the Minister cannot be satisfied that the environmental impacts and risks would be mitigated to an acceptable level.

Wastewater

51. The EMP activities will produce large quantities of wastewater, which poses significant risks such as contamination of surface and groundwater if they crack, split or leak. The EMP contains a Wastewater Management Plan, however the EMP does not sufficiently address the potential environmental impacts or risks of wastewater management and storage. Wastewater will be transferred between sites via underground 'gathering lines'. Valve pits will be installed every 1km, and where a leak is detected, wastewater can be 'purged' from the line. It is unclear how Tamboran will prevent the 1km flow of wastewater between valves from entering the environment and the EMP does not address the potential impacts and risks to the environment if this occurs. A change in flow volumes at each end of the gathering network will be used to identify potential leaks. Only if over 100 litres of wastewater is missing, it notified Tamboran of an imbalance and the leak is investigated. Setting a lower threshold is possible, however it would come with a higher risk of triggering a false alarm.[91] It may take up to 24 hours for Tamboran to respond to leaks.[92] ECNT submits that this is inadequate in reducing the risk of water contamination as low as reasonably practicable. Further, the EMP provides little to no information regarding the decommissioning of wastewater gathering lines which may pose significant environmental and operational risks for pastoralists.

52. The EMP proposes to deal with flowback water by evaporation followed by offsite disposal or recycled as stimulation make-up water. The environmental impacts of disposal of flowback fluid solids, sludges, brines and liners is also not sufficiently addressed in the EMP.

Cumulative impacts

53. Schedule 1 of the Regulations requires Tamboran to address "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity." Multiple gas companies propose to frack in the Beetaloo Basin and the EMP should assess its potential impacts on groundwater, surface water and water-dependent ecosystems in this context. We also note that there is considerable agricultural activity planned in the Beetaloo region, with cotton development proposed or underway for Newcastle Waters and Ucharonidge Stations, with associated biodiversity and water impacts. The EMP should thus also assess the

[90] Prof. Matthew Currell and Dr Christopher Ndehedehe, *SREBA Expert Review – Groundwater*, (2023) p 36.
[91] Shenandoah EMP, p. 115.
[92] Shenandoah EMP, p. 115.

potential cumulative impacts of agricultural development in combination with proposed gas development in the region.

Impacts on cultural values and sites

54. A reduction in water quantity or quality impacting traditional use and/or value of cultural sites was a key risk identified in the Pepper Inquiry.[93] First Nations people have long voiced their concerns about the impact of fracking in the NT, including the impact of water extraction and contamination of the Roper River. At a minimum, the Roper River should be addressed as a potential area of cultural significance which could be impacted by the project.

55. Part 4.3.3 of the EMP briefly outlines areas of cultural significance that could potentially be impacted by the project, however it does not adequately identify or address all potential risks, for example, the risk of water extraction or contamination on First Nations people, their sacred sites and sites of cultural significance. The Social, Cultural and Economic (SCE) studies that accompany the SREBA report highlight the sacred nature of water for First Nations people in the region and notes that people "worry regarding connectivity of sacred sites through the dependence of many sacred site features on water, both groundwater and quality and quantity of permanent water sources that may interconnect through streams, creeks etc"[94]. The concern among those who participated in the SCE studies is around the ability for environmental and cultural heritage protection mechanisms to adequately safeguard an interconnected system imbued sacred sites, and a concern that the "geological connectedness and potential impacts on these special sites may not have been fully understood in the assessment process"[95]. The full extent of impacts to sacred sites and sites of cultural significance should be assessed through an Environment Impact Assessment under the *Environment Protection Act 2019*.

56. Part 4.3.3 of the EMP briefly discusses existing and pending Certificates issued by Aboriginal Area Protection Authority (AAPA) under the *Northern Territory Aboriginal Sacred Sites Act (1989).* However, the Sacred Sites Act is limited to considerations of risks to sites that fall within the 'vicinity' of proposed work areas and hence does not capture potential risks to interconnected water sites that may be located further afield. Furthermore, each sacred site certificate application submitted to the AAPA is treated as a discrete set of proposed works making it difficult to assess cumulative impacts of work activities across a region. For this reason it is crucial that the impacts of the proposed EMP activities on cultural values or sites should be assessed cumulatively in addition to other existing and proposed projects in the region.

[93] NT Government, Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, *Background and Issues Paper* (20 February 2017).
[94] Dr Katherine Witt, Social, Cultural and Economic Studies of the SREBA for the Beetaloo Sub-basin - Appendix C - Cultural Practices in Water, (2022) p 15.
[95] Dr Katherine Witt, Social, Cultural and Economic Studies of the SREBA for the Beetaloo Sub-basin - Appendix C - Cultural Practices in Water, (2022) p 15.

57. Finally, concerns in relation to impacts to sacred sites as a result of fracking activities was given considerable attention throughout the Pepper Inquiry consultation process and is reflected in the final report[96]. There was a particular focus on the need to protect underground sacred sites given the nature of fracking activities including underground disruption, potential water draw down and contamination risks. As a result, the following recommendation was made: Recommendation 11.3 That the Sacred Sites Act be amended to protect all sub-surface features of a sacred site. This recommendation has not been implemented and is further grounds for requiring impacts to sacred sites and sites of cultural significance to be assessed through an Environmental Impact Assessment under the *Environment Protection Act 2019.*

The Shenandoah EMP should be referred for assessment under the *Environment Protection Biodiversity Conservation Act 1999.*

58. We have attached an EPBC Act Protected Matters Report generated on the Federal government's website. The Report indicates that there are a number of listed threatened species, migratory species and threatened ecological communities, including the Gouldian Finch, which may exist in the vicinity of the EMP project area. The online tool is used to help project proponents to identify whether a project should be referred for assessment under the EPBC Act in addition to a Territory environmental approvals process. The EPBC Act encourages proponents to take a cautious approach, referring projects that 'may' impact a matter of national environmental significance. Considering the number of matters of national environmental significance that may occur in the project area, and considering the project could impact biodiversity values, air and water pollution and water levels, the project should at a minimum, be referred for assessment under the EPBC Act. ECNT urges the Minister to refer the project to the Federal government for assessment.

59. In addition to these matters of national environmental significance, the government also recently expanded the water trigger to include shale gas fracking, particularly to address the impact of fracking in the NT on groundwater and surface water. The government described this as a "commonsense change" which will provide "the community with confidence that water resources and our environment are properly regulated and protected."[97] A 15 well fracking project proposed for the Beetaloo basin is exactly the type of project the community expect will be subject to the water trigger and EPBC Assessment, as soon as the water trigger amendment comes into effect. ECNT expects the NT government will be active in exercising its powers to ensure fracking projects proposed in the Beetaloo Basin will be referred for assessment under the EPBC Act.

[96] NT Government, Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, *Background and Issues Paper* (20 February 2017) p 284-286.
[97] Commonwealth, Parliamentary Debates, Senate, 5 December 2023, 6601 (Jenny McAllister, Senator).

The Shenandoah EMP should be rejected because it does not comply with NT law and policy.

Petroleum (Environment) Regulations 2016 (NT)

60. The object of the *Petroleum (Environment) Regulations 2016* (NT) (**Petroleum Environment Regulations**) is to "ensure that regulated activities are carried out in a manner: (a) consistent with the principles of ecologically sustainable development; and (b) by which the environmental impacts and environmental risks of the activities will be reduced to a level that is:(i) as low as reasonably practicable [(**ALARP**)]; and(ii) acceptable."[98] The Minister must consider and apply the principles of ecologically sustainable development in making a decision to approve an EMP.[99] Approval criteria for an EMP is that it demonstrates that the activity will meet the ALARP standard and be acceptable.[100] The NT Government notes that ALARP considers the level of consequence and cost, time and resources involved to mitigate a risk; a risk reduction measure can be considered as being reasonably practicable if the costs to implement it are not grossly disproportionate to the reduction in risk achieved.[101] Environment is broadly defined in the *Environment Protection Act 2019* (NT) to include "all aspects of the surroundings of humans including physical, biological, economic, cultural and social aspects."[102] This definition has been adopted by reference in the *Petroleum Act 1984* (NT).[103]

A. The Shenandoah EMP's impacts are not acceptable because they are inconsistent with global climate commitments.

61. According to the UN, no new gas projects may be approved if the world is to meet its climate targets. The 2023 UNEP emissions gap report notes that the lifetime emissions of all the existing gas, oil and coal projects producing or under-construction back in 2018 were sufficient to "emit more than 3.5 times the carbon budget available to limit warming to 1.5°C with 50 per cent probability, and almost the size of the budget available for 2°C with 67 per cent probability."[104] Remaining carbon budgets aligned with meeting the long-term goals of the Paris Agreement "require that much of the existing capital stock will need to be retired early... **Globally, this leaves no room for new fossil fuel infrastructure**, unless an even greater quantity of existing stock is stranded."[105]

62. One of the reasons why there is no room for new fossil fuel infrastructure is because there is a significant gap between promised action on climate change and the emissions needed to meet

[98] *Petroleum (Environment) Regulations 2016* (NT), s. 2.
[99] *Petroleum Act 1984* (NT), s. 6A; *Petroleum (Environment) Regulations 2016* (NT), s. 5A.
[100] *Petroleum (Environment) Regulations 2016* (NT), s. 9(1)(c).
[101] NT Government, *Environment Management Plan Content Guideline Onshore Petroleum Regulated Activities* (Dec. 2022).
[102] *Environment Protection Act 2019* (NT), s. 6.
[103] *Petroleum Act 1984* (NT), s. 5.
[104] United Nations Environment Programme, *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*, (2023) p. XXIII.
[105] United Nations Environment Programme, *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*, (2023) p. 35 (emphasis added).

global climate targets, and emissions from the energy sector must be reduced to close that gap. The Secretariat of the United Nations Framework Convention on Climate Change (**UNFCCC**) released a 2023 report synthesizing all global commitments under countries nationally determined contributions (**NDCs**) compared to emissions trajectories modelled by the Intergovernmental Panel on Climate Change (**IPCC**). The Secretariat concluded that the "absolute difference in the level of emissions by 2030 according to the latest NDCs and these IPCC scenarios is sizeable," as an additional 15.1 gigatonnes (**Gt**) of CO2-e of reductions would be needed to limit warming to 2 °C, and 22.9 Gt CO2-e to limit warming to 1.5 °C.[106] The United Nation's 2023 Production Gap Report focused on the need to reduce emissions from fossil production, and found that "governments are planning on producing around 110% more fossil fuels in 2030 than would be consistent with limiting warming to 1.5°C, and 69% more than would be consistent with limiting warming to 2°C."[107] This production gap demonstrates that Australia must reduce the amount of fossil fuels it produces to be consistent with global climate goals.

63. Approval of the Shenandoah EMP will thus contribute to climate change and the likelihood Australia is unable to meet the emissions reductions necessary from the fossil production sector to achieve global climate goals.

64. If these goals are not reached, the impacts will be unacceptable. Climate change is projected to increase the severity of impacts across natural and human systems, including loss of species, heat-humidity impacts on human health, losses of crop and fisheries yields.[108] Risks are increasing with every increment of warming, including, for example, 90% of coral reef decline at 1 degree of warming and greater than 99% of coral reefs declining at 2 degrees of warming and increases in human morbidity as temperature rises.[109]
65. Impacts in the NT will also be unacceptable. The Australian Academy of Science warns Darwin could have to contend with 265 days every year above 35C.[110] Short exposures to temperatures above 35°C with high humidity, or above 40°C with low humidity, can be lethal.[111] A 2023 study in Nature found that portions of the NT will fall outside of average temperature ranges suitable for human well-being,[112] making portions of the NT uninhabitable.[113] Less than fatal impacts on human health in the NT will include heat stress that can "exacerbate cardiovascular, renal and other chronic disease."[114]

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[106] Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, Fifth session, FCCC/PA/CMA/2023/12, United Arab Emirates, 30 November to 12 December 2023, *Nationally determined contributions under the Paris Agreement*, (14 Nov. 2023 general distribution) p. 6, para. 14.
[107] Stockholm Environment Institute, Climate Analytics, E3G, International Institute for Sustainable Development and United Nations Environment Programme, *The Production Gap: Phasing down or phasing up? Top fossil fuel producers plan even more extraction despite climate promises*, (2023) p. 4.
[108] IPCC, *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2023) p. 16.
[109] IPCC, *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2023) p. 16.
[110] Australian Academy of Science, *The Risks To Australia Of A 3°C Warmer World*, (2021).
[111] Senthold Asseng, et al., *The upper temperature thresholds of life*, 5 Lancet Planet Health (2021) e378–85.
[112] Timothy M. Lenton et al., *Quantifying the human cost of global warming*, 6 *Nature Sustainability* (2023) 1237–1247, Figure 9.
[113] Jamie Seidel, *Three Aussie towns set to become unliveable due to extreme heat*, (25 May 2023).
[114] CSIRO, *Climate change in the Northern Territory: State of the science and climate change impacts*, (2020) p. 28.

66. The Shenandoah EMP is not acceptable because it is inconsistent with climate goals that must be kept to avoid these significant environmental impacts.

B. Tamboran must offset all emissions for all fiscal years and not just fiscal year 2025 in order to meet the ALARP and acceptability standard, comply with best practice, and comply with Recommendation 9.8 of the Scientific Inquiry into Fracking.

67. Tamboran states that it will offset all of its 190,976 tCO2-e in financial year 2025, leaving zero residual emissions.[115] Tamboran assumes this is the only year it must meet the Safeguard Mechanism and fully offset its emissions (as discussed further below).[116] Tamboran chooses not to fully offset emissions from any other financial year.[117] By committing to offsetting its emissions in FY 2025, Tamboran suggests it has the potential to offset all of its emissions and that doing so is reasonably practicable. Choosing to not offset emissions when doing so is possible and reasonably practicable means it is not mitigating emissions to the ALARP level.

68. Reducing emissions to be net zero for all years would also be required to comply with international best practice. As summarised by the Commonwealth Department of Climate Change, Energy, the Environment and Water, reforms to the Safeguard Mechanism have recognised that international best practice for gas development requires net-zero emissions:

> New gas fields supplying existing liquefied natural gas facilities will be given international best practice baselines for the reservoir CO2 in their new fields. For these fields' reservoir CO2 emissions, best practice is zero given the existence of low-CO2 fields and opportunities for carbon capture and storage. Shale gas projects within the Beetaloo Basin will be required to have net-zero scope 1 emissions from the outset, consistent with existing Commonwealth Government commitments to work with the Northern Territory to support its implementation of recommendation 9.8 of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory.[118]

69. Lastly, the NT Government claims to have fully implemented recommendations of the Scientific Inquiry,[119] but doing so would require net-zero lifecycle emissions from this EMP. Recommendation 9.8 of the Scientific Inquiry required ensuring that there is "no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT."[120] As noted above, even with offsets and the sale of beneficial gas to third parties to reduce flaring (which would have its own Scope 3 emissions not reported in the EMP), the Shenandoah EMP has not offset all of its lifecycle emissions, as it will produce 196,826 tCO2-e. Thus, the

[115] Shenandoah EMP, p. 127, Table 26.
[116] Shenandoah EMP, p. 127, Table 26 (stating Tamboran "Assumes the NGERS safeguard 100 ktCO2 trigger has been reached and offset requirements triggered" for Financial Year 2025).
[117] Shenandoah EMP, p. 127, Table 26 (stating Tamboran "Assumes the NGERS safeguard 100 ktCO2 trigger has been reached and offset requirements triggered" for Financial Year 2025).
[118] Commonwealth Department of Climate Change, Energy, the Environment and Water, *Safeguard Mechanism Reforms* (May 2023), p. 3 (emphasis added).
[119] NT Government, *Total Implementation Progress* (2024).
[120] Pepper Inquiry Report, p. 239.

Shenandoah EMP has failed to fully offset its own emissions and approval of this EMP would thus be inconsistent with Recommendation 9.8.

Tamboran has not managed Shenandoah EMP's risks to be as low as reasonably practicable nor acceptable because the EMP lacks information and management plans required by NT policies and that are necessary to ensure risks are low and acceptable.

A. The EMP lacks information required under the Large Emitters Policy.

70. The NT Greenhouse Gas Emissions Management for New and Expanding Large Emitters Policy (**Large Emitters Policy**) identifies the NT Government's minimum requirements for the management of GHG emissions from new or expanding industrial and land use development projects.[121] It has been established in recognition of the Territory's target of net zero greenhouse gas emissions by 2050. The policy commenced on and is in effect from 1 September 2021.[122]

71. The Large Emitters Policy applies to petroleum projects that emit 100,000 tCO2-e in any financial year over the life cycle of a project, and this "threshold applies cumulatively to scope 1 emissions from all activities of an interest holder occurring in a financial year and requiring approval under the *Petroleum (Environment) Regulations 2016.*"[123]

72. Project proponents "subject to this policy must develop and implement a greenhouse gas abatement plan (**GGAP**) that has been tailored specifically for their project. A project's GGAP should be submitted for assessment as part of the usual process for a project to obtain an environmental authorisation."[124] In 2023, the NT Government released a policy statement clarifying its position regarding how the Large Emitters Policy applies to shale gas development. In this policy, the NT Government clarified that for "the avoidance of doubt, all applications for onshore gas production will require a GGAP regardless of the 100 000 tCO2-e scope 1 emissions in a financial year threshold contained in the Large Emitters Policy. The threshold in the Large Emitters Policy will continue to apply to the industry when seeking approvals for exploration, including appraisal, activities."[125]

73. The Shenandoah EMP contains no GGAP designed to meet the requirements of the Large Emitters Policy. The only reference to a GGAP in the EMP is a single sentence suggesting that, in the future, there will be a GGAP that "is updated annually based on actual emissions from the preceding year to ensure currency."[126]

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[121] NT Government, *Greenhouse Gas Emissions Management for New and Expanding Large Emitters* (Aug. 2021) (**Large Emitters Policy**), p. 1.
[122] Large Emitters Policy, p. 1.
[123] Large Emitters Policy, p. 6.
[124] Large Emitters Policy, p. 7.
[125] NT Government, *Policy Statement Management of Greenhouse Gas Emissions from the Onshore Gas Industry*, (May 2023).
[126] Shenandoah EMP, p. 127.

74. Further, the Shenandoah EMP lacks information that would be required by a GGAP. The requirements of a GGAP must be reflected in the Minister's decision to grant the EMP and in any conditions imposed on an environmental authorisation,[127] and thus the Minister should reject the EMP until this information is provided. A GGAP requires the following information not already included in the Shenandoah EMP:

i. A GGAP is required to demonstrate how the project will contribute "meaningfully" to the Territory's target of net zero emissions by 2050. A GGAP must also provide an "explanation of, and justification for, any proposed long-term and interim targets and how these will make a meaningful contribution to the Territory's emissions target."[128] An explanation or justification should be one that includes calculations showing how the project will be consistent with 2050 emissions goals. Tamboran commits to voluntarily offset only up to 18.4% of its emissions to meet the NT net zero by 2050 target, without any analysis or justification as to whether this is sufficient.[129]

ii. A GGAP must estimate the project's net Scope 2 emissions and how these emissions will contribute to the Territory's overall emissions profile.[130] There is no quantification of what the project's Scope 2 emissions are. There is likewise no demonstration of how these Scope 2 emissions will contribute to the Territory's profile.

iii. A GGAP must provide an estimate of the project's Scope 3 emissions.[131] There is no such estimate of Scope 3 emissions including from the sale of beneficial use gas as proposed in the Shenandoah EMP.

iv. A GGAP must demonstrate that all reasonable and practical measures have been applied to avoid and mitigate emissions through best practice design, process, technology, and management. [132] The Shenandoah EMP does not demonstrate that all such measures have been applied in years other than 2025 to make all of its emissions net-zero.

v. Lastly, a GGAP must provide a schedule for periodic public reporting on implementation and progress against the interim and overarching targets and any changes that have had to be made to the strategies proposed in the GGAP to deliver on the targets.[133] No such schedule appears in the EMP.

[127] The 2023 Policy Statement clarifying the Large Emitters Policy stated that GGAP "requirements will be reflected in regulatory decisions made under the Environment Protection Act 2019 and Petroleum (Environment) Regulations 2016. The commitments made in a GGAP will be the subject of appropriate environmental authorisation conditions in accordance with regulatory powers: NT Government, *Policy Statement Management of Greenhouse Gas Emissions from the Onshore Gas Industry*, (May 2023).
[128] Large Emitters Policy, p. 8.
[129] Shenandoah EMP, p. 126.
[130] Large Emitters Policy, p. 8.
[131] Large Emitters Policy, p. 8.
[132] Large Emitters Policy, p. 8.
[133] Large Emitters Policy, p. 8.

75. This information is also required for Tamboran to demonstrate that its impacts will be as low as reasonably practicable and acceptable, and thus the EMP should be rejected as it is inconsistent with NT law.

The Shenandoah EMP does not meet additional requirements of the Petroleum Environment Regulations because it is not appropriate for the nature and scale of the regulated activity.

76. The approval criteria for an EMP include that the plan must be appropriate for the nature and scale of the regulated activity to which the plan relates.[134] As noted above, actual emissions from this project have the potential to reach 607,071 tCO2-e assuming an average of 90 days per well test, or up to 1,895,598 tCO2-e for worst case well-testing (300 days).[135] Additionally, the project will require over 1.5 billion litres of water.[136] In sum, this project will potentially result in over 1.8 Mt of CO2-e in direct emissions alone, and require over a billion litres of water that is being conducted for the purpose of supporting gas export through an LNG facility that will generate 1.4 billion tonnes of direct emissions over 20 years.[137] A project of this scale must provide more robust studies and details of the many communities and ecosystems across the Territory that could be impacted by its climate emissions and water extraction.

The Shenandoah EMP does not meet the criteria in Schedule 1 of the Petroleum Environment Regulations because it does not include an adequate description of the process used to assess environmental impacts.

77. The approval criteria for the Minister in assessing an EMP include ensuring that the plan includes all information required by Schedule 1 of the Petroleum Environment Regulations. Schedule 1 requires an EMP to include "a description of the process used to assess the environmental impacts and environmental risks."[138] The EMP fails to meet this criterion because the EMP does not include an adequate description of the process used to assess the impacts of the project to the climate, including a clear description of assumptions used in their calculations, which is why there is significant uncertainty about the range of emissions likely to result from the project, as described in previous sections. Compliance with this requirement would necessitate a transparent explanation of the assumptions behind GHG emissions estimates and justification of these assumptions, which would result in a clear range of emissions that would include the potential emissions under the worst case scenario.

[134] *Petroleum (Environment) Regulations 2016* (NT), s. 9(1)(b).
[135] Note: even higher emissions are possible if the beneficial use gas program is not implemented.
[136] Shenandoah EMP, p. 7 (375 million litres of water required per year, approximately, times four years of operations is 1.5 billion litres).
[137] The Australia Institute, *Emissions from the Tamboran NT LNG Facility* (Aug. 2023).
[138] *Petroleum (Environment) Regulations 2016* (NT), Schedule 1, s. 3.

The Shenandoah EMP does not meet the criteria in Schedule 1 of the Petroleum Environment Regulations because it does not comprehensively describe the regulated activity, detail all environmental impacts of project, or assess the impact of cumulative emissions on the climate and region.

78. Schedule 1 also requires an EMP to "give a comprehensive description of the regulated activity to which it relates" and provide the "details of all environmental impacts and environmental risks of the regulated activity described in the plan and an assessment of those impacts and risks."[139] This assessment must include "all the environmental impacts and environmental risks arising directly or indirectly from: (i) all aspects of the regulated activity; and (ii) potential emergency conditions" and "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity." By not accurately calculating the worst case scenario of emissions, the EMP has not given a comprehensive description of the regulated activity, nor has it detailed its environmental risks and impacts. The EMP does not list GHGs from 'emergency conditions.' The EMP also does not provide an assessment of the impacts of the project and the cumulative emissions of other projects across the Basin on the climate, nor the way these changes in the climate will affect the area, including the project and the activities near the permit area.

A. The Shenandoah EMP does not keep emissions to as low as reasonably practicable because flaring efficiencies could be improved and emissions from other processes could be captured.

79. The EMP states that Tamboran will use a flare with a "tip combustion efficiency of 98%."[140] While this may seem high, it is allowing for thousands of tonnes of potent methane (among other GHGs that are greater climate change drivers than CO_2) to enter the atmosphere. A tip efficiency of 99% would cut those methane emissions in half, while an efficiency of 99.9% would obviously be even better. Achieving such flare combustion efficiencies are possible and practicable with the right technologies and maintenance practices; in other industries, flare efficiencies of 99.99% or even more are mandatory.[141] The EU has been contemplating requiring 99% efficiencies in flaring, showing that these efficiency rates are possible.[142]

80. The risk of emissions from flaring are particularly significant in this case, given the scale of the project. The GHG emissions analysis in the EMP states that 829 tonnes of methane will be vented directly to the atmosphere during well completions.[143] Yet there are ways to capture this methane and send it to a flare instead, known as reduced emission completions (**REC**).[144] The EMP states that the Methane Emissions Management Plan includes these RECs,[145] but it is clear from the emissions table that RECs are not being fully implemented due to the amount of

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[139] *Petroleum (Environment) Regulations 2016* (NT), Schedule 1, ss. 1, 3.
[140] Shenandoah EMP, p. 7, Table 1.
[141] 40 United States Code of Federal Regulations (C.F.R.) § 63.1203.
[142] Nicholas Kurmayer, *Oil and gas industry jittery as EU nears deal on methane leakage* (12 November 2023).
[143] Shenandoah EMP, p. 123, Table 24.
[144] U.S. EPA, *Reduced Emission Well Completions and Workovers* (2023).
[145] Shenandoah EMP, p. 224.

venting. Considering the potential to reduce the climate change impacts of these emissions, the failure of Tamboran to implement the appropriate technologies and processes to do so is a violation of the ALARP standard.

81. Tamboran has also failed to manage the emissions risks from other processes to the ALARP level. The EMP states that wastewater will be treated onsite "though evaporation or other mechanical water treatment options."[146] According to the EMP's GHG emissions tally, this will account for 60 tonnes of methane being released directly into the atmosphere.[147] These emissions could be reduced by holding the water in enclosed tanks and capturing and flaring the gases, including methane, emitted by the liquids. Similarly, drill cuttings could also be stored in an enclosed space so that gases could be captured, saving the 19.1 tonnes of methane the EMP states they will emit to the atmosphere.[148] The failure of Tamboran to commit to implementing the systems necessary for containing and flaring these emissions in this EMP is a violation of the ALARP standard.

The Shenandoah EMP should be rejected as it does not contain an Authority Certificate under s 22 of the *Northern Territory Aboriginal Sacred Sites Act 1989*

82. Before approving the plan, the Minister must be reasonably satisfied that the EMP includes an Authority Certificate under s 22 of the *Northern Territory Aboriginal Sacred Sites Act 1989* in relation to the land on which the activity will be carried out. The EMP does not contain an Authority Certificate and cannot be approved by the Minister under Regulation 9(1)(d).

The Shenandoah EMP should be rejected as it does not comply with the Code of Practice

83. The Code of Practice: Onshore Petroleum Activities in the Northern Territory (**Onshore Code**) provides minimum standards that the onshore petroleum industry must adhere to in the Territory.[149] Tamboran's proposed EMP violates several of these standards, as follows.

A. The EMP fails to comply with mandatory requirements, including those related to the monitoring of methane and other compounds and leak classification.

84. The Onshore Code imposes a mandatory requirement for a basin-wide methane assessment for at least six months prior to exploration and appraisal activities commencing that assesses natural and anthropogenic sources and amounts of methane emissions.[150] This assessment must

[146] Shenandoah EMP, p. 8, Table 1.
[147] Shenandoah EMP, p. 122, Table 24.
[148] Shenandoah EMP, p. 122, Table 24.
[149] NT Government, *Code of Practice: Onshore Petroleum Activities in the NT* (NT) (**Onshore Code**), s. 3.2 (noting the Onshore Code provides mandatory requirements).
[150] Onshore Code, s. D.4.1.2(a) (stating a "Methane assessment (i.e. mobile surveys of ambient methane concentration; identification and location of main methane sources; quantification of emission rates if possible) must be undertaken for the region or catchment for at least six months prior to the granting of exploration approvals involving hydraulic fracturing").

also include measurements of ambient air for CO_2, oxides of nitrogen (**NOx**) and particulate matter (**PM**) across the gas-producing basin.[151] Baseline methane monitoring studies conducted by CSIRO do not appear to include measurements of NOx or PM.[152] The Shenandoah EMP provides no information about whether existing surveys satisfy requirements of the Onshore Code, nor whether the EMP may conduct monitoring to fill gaps in baseline data, such as for NOx, or PM concentrations.[153]

85. The Onshore Code also requires a methane assessment across the "permit or licence area and adjacent areas" called a Regional Methane Assessment Programme (**RMAP**).[154] This assessment must identify and locate "the sources and, where possible, estimating the emission rate from each source either by direct measurement or other estimation methods" across the permit area and adjacent areas.[155] The RMAP "must be submitted for approval" and "must be undertaken at the following frequency… three baseline surveys within six months prior to the granting of exploration approvals involving hydraulic fracturing."[156] The Shenandoah EMP does not contain any references to a RMAP, nor does it indicate that one will be submitted for approval or whether any existing studies satisfy this requirement.

86. Finally, the Onshore Code requires a Methane Emissions Management Plan to reduce emissions.[157] The Methane Emissions Management Plan must classify leaks according to Section D.5.3 of the Onshore Code, which requires classifying leaks from any gathering system to be a 'significant' leak if the leak gives a sustained reading greater than 500 ppm (by volume) for a 15 second duration.

87. The Shenandoah EMP 's Methane Emissions Management Plan is inadequate because it will not monitor emissions from this project's gathering system and misclassifies the significance of methane leaks from this system. The Shenandoah EMP's gathering system will be built to "facilitate the transfer of high volumes of fluid and produced hydrocarbons safely and efficiently between well pads to a centralised storage area to enable centralised management and fluid recycling from the product that is produced from multiple wells to a central point."[158] The EMP also states that a methane gathering system may also be used: "Produced hydrocarbons will either be flared onsite or gathered to a centralised flare for management (such as Shenandoah S2)."[159] These networks have a significant risk of leaking methane and other GHGs, which is evident in the EMP's description of leak testing necessary for the wastewater management

[151] Onshore Code, s. D.4.1.2(c).
[152] *See, e.g., CSIRO, Baseline monitoring of methane emissions in the Beetaloo Sub-basin*, (2019) (stating "methane was the principal gas of interest, carbon dioxide and ethane were also measured during the first campaign to assist with identifying the source of emissions" but not monitoring for oxides of nitrogen or particulate matter).
[153] *See generally* Tamboran, *Beetaloo Exploration Program, Methane Emission Management Plan, Appendix I to the Shenandoah EMP* (2023) (not describing any regional methane monitoring plan, and limiting monitoring to methane measurements conducted once every six months of the wells and well pads, measurements of flared gas, and other equipment leak checks specific to well pad infrastructure).
[154] Onshore Code, s. D.4.2.1.
[155] Onshore Code, s. D.4.2.1.
[156] Onshore Code, s. D.4.2.2 (Mandatory requirements).
[157] Onshore Code, s. D.5.1.1-2.
[158] Shenandoah EMP, p. 62, Section 3.6.6.
[159] Shenandoah EMP, p. 88.

system,[160] and statement that "Where a gas gathering line is used, pressure monitoring and 6 monthly pipeline inspections will be undertaken to detect pipeline leakage as described in the methane emission management plan."[161] The Shenandoah Methane Emissions Management Plan, however, does not contain requirements for monitoring of these networks. Moreover, the plan incorrectly classifies leaks from gathering systems per the Code, failing to accurately classify a leak of 500 ppm from a gathering system as a significant leak.[162] The EMP's description of the gathering system similarly does not mention what constitutes a significant leak.[163] The Methane Emissions Management Plan therefore fails to comply with proper leak classification as required by the Onshore Code.

B. The EMP fails to comply with preferred requirements.

88. Under the Onshore Code, "preferred requirements" are practices, methods and techniques which should generally be followed by interest holders unless there is a convincing justification why they cannot be followed and any alternative practice, method or technique that will be followed will achieve the principle or result in no greater environmental harm.[164] The Onshore Code lists as a preferred requirement that the Methane Emissions Management Plan comply with sections of Title 40 of the Code of Federal Regulations related to air quality for new stationary sources, including section 60.5397a related to fugitive emissions.[165] This section imposes several requirements, including that operators of a facility must conduct an initial monitoring survey of fugitive methane emissions within 90 days of the startup of production.[166]

89. The Shenandoah Methane Emissions Management Plan makes no such commitment, limiting mandatory monitoring to once every six months.[167] No justification is provided for this departure from the preferred requirements, nor is there any explanation of how the alternative practice will ensure there is no greater environmental harm. The EMP therefore fails to comply with the requirements of the Onshore Code.

The Shenandoah EMP should be rejected because it does not comply with Commonwealth obligations under the Safeguard Mechanism.

90. One of the primary objectives of the *National Greenhouse and Energy Reporting Act 2007* (Cth) (**NGERA**) is to meet "Australia's greenhouse gas emissions reduction targets" and to ensure that "total net safeguard emissions for all of the financial years between 1 July 2020 and 30 June 2030 do not exceed a total of 1,233 million tonnes of carbon dioxide equivalence."[168] To meet

[160] Shenandoah EMP, p. 69.
[161] Shenandoah EMP, p. 89.
[162] Shenandoah EMP, Appendix I, p. 5, Table 3 (classifying significant leaks as those resulting in >5000 ppm (or 10% of the Lower Explosive Limit) when measured at 150 mm above the leak source or a Liquid Petroleum (condensate/oil) loss of containment that exceeds 200 L or the leak is too large or not safe to measure).
[163] *See, e.g.,* Shenandoah EMP, p. 69 (describing leak detection from the gathering system).
[164] Onshore Code, s. 3.2(c).
[165] Onshore Code, s. D.5.1.3(a).
[166] 40 United States Code of Federal Regulations (**C.F.R.**) § 60.5397a(f)(1).
[167] Shenandoah EMP, Appendix I, p. 3, Table 2.
[168] *National Greenhouse and Energy Reporting Act 2007* (Cth), s 3(2).

these goals, NGERA instituted the Safeguard Mechanism that aims to "ensure that net covered emissions of greenhouse gases from the operation of a designated large facility do not exceed the baseline applicable to the facility."[169]

91. The Safeguard Mechanism applies to "designated large facilities" during "monitoring periods." A designated large facility is one that generates more than 100,000 tCO2-e during a financial year[170] of scope 1 emissions. [171] If a facility emits more than 100,000 tCO2-e in a financial year, then the financial year becomes a monitoring period for the facility.[172] An "excess emissions situation exists" when net emissions over a monitoring period exceed baseline emissions.[173] The baseline emissions for a shale gas extraction facility is set by regulations as zero.[174] The responsible emitter for a large facility has a duty to ensure that an excess emissions situation does not exist for that facility's monitoring period.[175] Thus, at a minimum, responsible emitters for a shale gas extraction facility must ensure net-zero emissions beginning in the financial year (its monitoring period) in which it was a designated large facility.

A. The Shenandoah EMP must demonstrate that it can offset all Scope 1 emissions to comply with the Safeguard Mechanism.

92. Total Scope 1 emissions that could be generated from the Shenandoah EMP, as demonstrated above, are at least 1,895,598 tCO2-e. Tamboran must commit to offsetting all unmitigated emissions that occur from the project and demonstrate that there are sufficient carbon credits to fully offset those emissions in the years that the Safeguard Mechanism applies.

93. Tamboran has failed to demonstrate in the EMP that it can find the offsets necessary to offset these levels of emissions across the life of the project, and that those offsets would be of the integrity necessary to convincingly counterbalance the immediate emissions of hundreds of thousands of tonnes of carbon and methane, among other GHGs, into the atmosphere.

94. The availability and quality of sufficient credits to offset the activities of the EMP and the other activities of the Basin are presently in doubt. The Minister for the Environment is undertaking an audit of offsets across the country, and creating a new offsets standard and independent body to monitor compliance because "there has been no reporting to track whether developers are actually delivering on their responsibilities."176 These government actions are no doubt based in part on the work of various researchers showing problems with the integrity of many offsets. This work has found, for example, that one of the most widely-used offsets, human-induced

[169] *National Greenhouse and Energy Reporting Act 2007* (Cth), Part 3H.
[170] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 22XJ (A facility is a "designated large facility for a financial year" if the "total amount of covered emissions of greenhouse gases from the operation of the facility during the financial year has a carbon dioxide equivalence" ("CO2-e") that "exceeds the number specified in the safeguard rules"); *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015* (Cth), s. 8, (setting 100,000 as the number for the purposes of Section 22XJ of NGERA 2007).
[171] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 22XI.
[172] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 22XG.
[173] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 22XE(1).
[174] *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015* (Cth), s. 10(2).
[175] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 22XF.
[176] Minister of Environment and Water, *Government launches environmental offsets crackdown* (29 June 2023).

generation projects, are high risk for having their integrity questioned or compromised,177 and have been significantly over-credited.178

95. At a more fundamental level, land-based carbon offsets are, given their relative volume, likely to be the vast majority of those used to offset the emissions from this and other Beetaloo Basin gas projects. Yet, these kinds of offsets are known for being more susceptible to having integrity issues, and in particular to be non-additional and non-permanent.179 Claims that such land-based offsets can "cancel out" emissions from fossil fuel combustion are therefore dubious at best.

96. In light of these doubts about the validity of carbon credits, it is all the more critical that Tamboran demonstrate in its EMP that it will be able to access sufficient offsets to cover the full potential emissions of its project, even in the context of other projects around it similarly seeking offsets, and that these offsets will be of the highest integrity. It has failed to do so.

B. The Shenandoah EMP fails to account for the broad definition of a 'facility' under the Safeguard Mechanism and does not offset the emissions from all ancillary activities that are part of its single enterprise to sell gas from EPs 98 and 117, including from export.

97. The Safeguard Mechanism broadly defines a "facility," which is consistent with a general principle of environmental assessments that activities that are part of a single enterprise should be assessed together and not artificially segmented.[180]

98. For the following three reasons, a shale gas extraction facility involves all ancillary activities, including exploration, production and export, when the activities form part of a single enterprise.

99. First, the Safeguard Mechanism broadly defines a facility to be an "activity, or a series of activities (including ancillary activities) that involve greenhouse gas emissions" and that "form a single undertaking or enterprise and meet the requirements of the regulations."[181]

100. Second, a "shale gas extraction facility" explicitly contemplates other activities other than exploration or extraction will be part of the facility. A facility can be a "shale gas extraction facility" if the "activity, or the series of activities, that constitutes the facility is or includes the extraction of gas" or "the exploration of a geological formation that contains shale gas," and

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[177] Carbon Integrity Project, *Carbon Integrity Explorer: Human-Induced Regeneration (HIR)*.
[178] Andrew Macintosh, et al, *Summary Results of Analysis of the Integrity Risk and Performance of Human-induced Regeneration (HIR) Projects using CEA data*, (2023), as in Climate Analytics, *Emissions impossible Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates* (2023).
[179] For a summary of some of these well-documented issues, see, for example, Climate Analytics, *Why offsets are not a viable alternative to cutting emissions* (2023).
[180] *See, e.g., Petroleum (Environment) Regulations 2016* (Cth), Schedule 1, s. 3(2)(b) (requiring "all aspects of the regulated activity" to be assessed, including the cumulative effects of those impacts and risks when considered with each other").
[181] *National Greenhouse and Energy Reporting Act 2007* (Cth), s. 9(1). *See also National Greenhouse and Energy Reporting Act 2007* (Cth), s. 7. ("activity" is also broadly defined to include a condition, circumstance, or state of affairs relating to any other matter or thing).

would require fracking to extract the gas from a formation that, if fully exploited, would generate more than 100 million tonnes of CO2-e.[182]

101. Third, the Australian Government's Clean Energy Regulator notes that facilities subject to the Safeguard Mechanism may involve a series of activities that each "may produce several different products, each with different emissions sources that can contribute to the facility's overall emissions-intensity."[183]

102. Under this broad definition of a 'facility,' the export of the gas should qualify as an ancillary activity to exploration and appraisal of shale gas when the enterprise's ultimate purpose is the export of the shale gas. Tamboran must estimate emissions from the full lifecycle of the gas being appraised in EPs 98 and 117, including its transport and export, and account for these emissions in calculating which years it will be subject to the Safeguard Mechanism and how much CO2-e it must offset. Tamboran should also demonstrate that these emissions do not threaten the goal of total net safeguard emissions for all of the financial years between 1 July 2020 and 30 June 2030 to be less than 1,233 million tCO2-e.

If you have any questions regarding this submission, please contact Kirsty Howey at kirsty.howey@ecnt.org.

Yours sincerely,

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Director	Freshwater Campaigner	Climate Campaigner
Environment Centre NT	Environment Centre NT	Environment Centre NT

[182] *National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015* (Cth), s. 54.

[183] Australian Government, Clean Energy Regulator, *Baselines for financial years ending before 1 July 2023* (28 Jul. 2023).

ATTACHMENTS

1) Prof. Matthew Currell and Dr Christopher Ndehedehe, *SREBA Expert Review – Groundwater*, (2023).

2) Prof. Matthew Currell and Dr Christopher Ndehedehe, *The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values,* (2022).

3) Thomas Houlie and Bill Hare, *Emissions impossible: Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates*, (October 2023).

4) Letter from Australian water experts to the Hon. Natasha Fyles titled 'Poor practice water planning in the Northern Territory', (dated 23 November 2022).

5) EPBC Act Protected Matters Report, generated on 8 January 2024.

6) The Australia Institute, *Emissions from the Tamboran NT LNG facility* (Aug. 2023).

7) David T. Allen et al., *Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers*, 49 *Environ. Sci. Technol*. (2015) 633.

8) Benjamin Luck et al., *Multiday Measurements of Pneumatic Controller Emissions Reveal the Frequency of Abnormal Emissions Behavior at Natural Gas Gathering Stations*, 6 *Environ. Sci. Technol. Lett*. (2019) 348.

9) Stefan Schwietzke et al., *Improved Mechanistic Understanding of Natural Gas Methane Emissions from Spatially Resolved Aircraft Measurements*, 51 *Environ. Sci. Technol*. (2017) 7286.

10) Timothy L. Vaughn et al., Temporal variability largely explains top-down/bottom-up differences in methane emission estimates from a natural gas production region, 115(46) *PNAS* (2018) 1172.

11) Jeffrey S. Rutherford et al., *Closing the methane gap in US oil and natural gas production emissions inventories*, 12:4715 *Nature Communications* (2021).

12) Ramón A. Alvarez et al, *Assessment of methane emissions from the U.S. oil and gas supply chain* 361 *Science* (2018) 6398.

13) Mary Kang et al., *Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania*, 111 *PNAS* (2014) 18173.

14) IPCC, *AR6 - Climate Change 2021, The Physical Science Basis - Chapter 7*, (August 2021) 1017.

15) Timothy M. Lenton et al., *Climate tipping points — too risky to bet against*, 575 (7784) *Nature* (2019) 592.

16) Ramón A. Alvarez et al, 361 *Science* (2018) 6398.Genevieve Plant et al., *Inefficient and unlit natural gas flares both emit large quantities of methane* 377 *Science* (2022) 1566.

17) United Nations Environment Programme, *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*, (2023) p. XXIII.

18) Stockholm Environment Institute, Climate Analytics, E3G, International Institute for Sustainable Development and United Nations Environment Programme, *The Production Gap: Phasing down or phasing up? Top fossil fuel producers plan even more extraction despite climate promises*, (2023).

19) IPCC, *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2023).

20) Australian Academy of Science, *The Risks To Australia Of A 3°C Warmer World*, (2021).

21) Senthold Asseng, et al., *The upper temperature thresholds of life*, 5 Lancet Planet Health (2021).

22) Timothy M. Lenton et al., *Quantifying the human cost of global warming*, 6 *Nature Sustainability* (2023) 1237–1247.

23) CSIRO, *Climate change in the Northern Territory: State of the science and climate change impacts*, (2020).

SREBA Expert Review – Groundwater

Professor Matthew Currell[1,2] & Dr Christopher Ndehedehe[2]

Introduction & Summary findings

The Beetaloo Strategic Regional Environmental and Baseline Assessment (SREBA) is a series of studies and datasets commissioned by the NT Government, in response to the findings and recommendations of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (Pepper Inquiry). This document contains a review of the SREBA studies relating to groundwater, commissioned by the Environment Centre, NT. The scope of the review encompasses analysis of the extent to which the SREBA studies and datasets released in 2023 have addressed knowledge gaps regarding groundwater, that were identified as needing to be addressed, via recommendations of the Inquiry (outlined in Chapter 7 of the final report, and the SREBA Framework), prior to the commencement of an onshore gas industry in the region.

This review represents the independent expert opinions of the authors. While it is not related to any legal proceedings, it has been prepared in accordance with the Northern Territory Expert Witness Code of Conduct (2015) section 2 which states that: "An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the Court impartially on matters relevant to the area of expertise of the witness."

This review identified the following areas where SREBA studies have largely addressed key objectives/knowledge gaps identified in the Pepper Inquiry:

- Monitoring data throughout most of the Cambrian Limestone Aquifer (CLA) system, encompassing the Tindall, Gum Ridge and Montijenni Limestone units, provides suitable baseline characterisation of groundwater levels over a range of climatic states. It should be noted that monitoring bore coverage (and thus baseline data) remains limited in certain key areas though. The SREBA area is of considerable size, warranting an extensive bore network to collect such data.

- Connectivity between the lower and upper CLA hydrogeological units - e.g., Anthony Lagoon and Gum Ridge Formations is relatively well-understood through analysis of groundwater level, hydrochemistry data and hydraulic testing – again noting that the density of nested monitoring bores is limited in some areas.

- Major groundwater flow-paths in the CLA, and discharge areas for these - e.g., Mataranka Springs, Roper River and Flora River have been further characterised (although these were known prior to the SREBA). Source aquifer(s) and flow-paths to the springs associated with these flow paths are less well-understood.

- Long-term average diffuse groundwater recharge rates for the CLA are relatively well-constrained, through analysis of multiple independent recharge estimation

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[2] Australian Rivers Institute, Griffith University

techniques; although coverage of recharge data and the degree of confidence in recharge rate estimates is better in certain areas than others.

This review identified the following areas where SREBA studies have not addressed key objectives/knowledge gasps identified in the Pepper Inquiry:

- There is a lack of groundwater monitoring bores - particularly nested sites, to characterise the groundwater level behaviour and flow gradients in the aquifer units below the CLA - e.g., Neoproterozoic sandstones, Kalkarindji Suite Volcanics, and Mesoproterozoic Beetaloo sub-basin formations (the latter of which are potential targets for shale gas development).

- There are certain areas where CLA groundwater levels and flow paths remain relatively poorly documented, such as at the edges of the Wiso and Georgina Basins, and above the Daly Waters high.

- There is limited understanding of the flow paths and water sources to key groundwater discharge features in the SREBA area, e.g., Top Springs and Hot Springs Valley, and the rates and mechanisms of groundwater discharge to these and other discharge features – e.g., Flora River springs.

- There remain substantial knowledge gaps regarding the geological architecture of the SREBA area, from the deep Beetaloo Basin rocks through to the shallow Cambrian and Cretaceous aquifers. Understanding of inter-aquifer (and inter-basin) connectivity, particularly between rocks that may be targeted for shale gas development and the overlying shallow aquifers is localised to a handful of bore sites monitoring different depths in the geological sequence. Many additional nested monitoring bore sites and other scientific studies adopting multiple lines of evidence (e.g., geophysics, geology, water and gas isotopes, and water level gradients) are required to establish the level of inter-aquifer connectivity across different areas of the SREBA. Current understanding of connectivity between a) Neoproterozoic and overlying Cambrian aquifers, and b) Beetaloo sub-basin rocks and shallower aquifers, remains very limited. This results in ongoing uncertainty regarding likely impacts of deep shale gas extraction on shallow aquifers.

- Preliminary data (mostly from environmental tracer sampling) indicate that there are areas where there is likely to be substantial connectivity between deep aquifer units and the shallow CLA (and/or springs), where groundwater discharge from deep units occurs. Such areas - where connectivity between the Beetaloo basin rocks and overlying Cambrian aquifer(s) may be considerable (e.g., Daly Waters High, and OT Downs sub-basin), do not appear to have been extensively drilled with monitoring bores or characterised with geophysics and hydraulic testing, to establish the level of vertical connectivity. The extent of these areas, and the potential impacts of increased water (or hydrocarbon) extraction from different depths in these regions (e.g., on inter-aquifer leakage and spring discharge rates) have also not been established.

- Recharge mechanisms and dynamics (e.g., variability of recharge with respect to key climatic variables and events), remain poorly understood. Localised recharge rates, and the relative importance of diffuse vs. preferential/focussed recharge, remain largely unknown in the SREBA area. While some additional analysis of recharge via preferential flow (e.g. sinkhole recharge) has been included in the reporting, SREBA studies have not generated a significant amount of new data to inform a more comprehensive quantification of recharge associated with preferential flow.

- The role of major climatic events on recharge (e.g., through rare, episodic periods of extended high rainfall), particularly in the arid parts of the SREBA, are also poorly understood. Such events are important in the consideration of water balances, and appropriate long-term sustainable extraction rates. The potential influence of climate change – e.g., increasing temperatures and evapotranspiration rates on recharge, which is also critical to water balance analyses going forward, does not appear to have been analysed.

- Reliance on numerical modelling to estimate recharge rates – a primary technique relied upon in updated regional water resources assessments in the SREBA area - must consider the high possibility of model non-uniqueness (due to uncertainty of multiple different model input parameters). This means that model calibration may not effectively constrain rates of recharge within robust and precise ranges.

- Additional analysis of remote sensing data can help to constrain recharge and its dependence on climatic variables, as well as understanding the importance of groundwater in sustaining surface water and vegetation through different climatic periods. Preliminary data analysed in this study and in the SREBA studies, indicate that both recharge rates and the permanence of surface water (connected to groundwater) vary considerably with yearly climate, undergoing periods when recharge rates are low, and vegetation becomes strongly dependent on groundwater. There remain considerable unknowns with respect to climate-groundwater-surface water interactions and resilience of these systems. These interactions must be understood to develop robust estimates of sustainable yields from the aquifer system.

- Estimation of sustainable groundwater extraction rates for the CLA would require considerable further data and analysis. This should encompass a comprehensive understanding of groundwater discharge rates and mechanisms (which sustain surface water, vegetation, and other GDEs) and potential changes to these under future climate and development scenarios. Current sustainable yield estimation appears to have been largely conducted using water balance estimates derived from groundwater numerical modelling; however, the full methodology and assumptions are not available to be reviewed in detail, precluding a full analysis of the appropriateness, and level of uncertainty associated with these.

- Data gaps relating to the hydrogeological parameters, water balance and inter-aquifer connectivity for the aquifer units below the CLA (e.g. Neoproterozoic sandstones) mean that sustainable extraction rates from these units cannot be determined, and require substantial additional information.

- There remains a lack of groundwater quality data for certain aquifers and hydrostratigraphic units – particularly those below the Cambrian Limestone Aquifer. Very few analyses have been conducted of groundwater quality/hydrochemistry from the Bukalara Sandstone, Antrim Plateau Volcanics, or deeper units within the Beetaloo sub-basin (shale gas exploration targets).

- There has been a lack of detailed characterisation of the major hydrogeochemical processes that control groundwater quality in different aquifers / units within the SREBA area (as opposed to basic characterisation of hydrochemical parameters, which is relatively extensive for the CLA).

- There is a lack of vertical profiling of groundwater quality/geochemistry with depth, e.g., from the CLA down into the underlying Proterozoic units, encompassing horizontal transects that capture variability in these vertical profiles (an explicit knowledge gap highlighted in the SREBA Framework objectives). This prevents a clear understanding of how water quality and geochemistry vary with respect to geological structure and layering, the key processes that control water quality, and future risks associated with water and/or hydrocarbon extraction (such as inter-aquifer mixing, water-rock interactions and solute migration).

- Limited data exist for characterising different types and sources of methane occurring throughout the aquifer system – e.g., extensive datasets for methane concentrations and isotopic composition in different aquifers. Methane is likely to be an important potential contaminant associated with shale gas activity, meaning this is an important knowledge gap. Coverage of data for groundwater microbiological analyses and trace/minor water quality components, that are also important potential indicators of water quality impacts associated with unconventional gas development, are also limited.

- Characterisation of key isotopic end-member compositions of different waters within the SREBA aquifer system, to enable future analysis of potential causes of any changes in groundwater quality (e.g., due to inter-aquifer mixing induced by greater rates of groundwater extraction, fugitive gas migration in response to gas development, or leakages/surface spills of fracking fluids) is generally lacking.

Extent to which data presented in SREBA address objectives/knowledge gaps identified in the Fracking Inquiry

Here we review the major objectives of the SREBA framework relating to groundwater, and analyse the extent to which the SREBA studies and datasets have addressed these. The review examines each of the objectives outlined in section 3 of the SREBA Framework (2020). For relevant background on the major aquifers within and overlying the Beetaloo sub-basin (the target for unconventional gas extraction), readers are referred to the SREBA regional report and references therein (DEPWS, 2022a).

Objective 1: Establish a baseline for groundwater (and surface water[3]) hydrology over a period that is representative of the climatic cycles of the area and of the geological and geomorphological variation across the region

Groundwater monitoring data have been compiled and are presented in various SREBA reports, including Amery and Tickell (2022), ELA (2022) and the SREBA Regional Report (DEPWS, 2022a). This review examined whether these data, and their analysis, provide comprehensive spatial and temporal coverage of groundwater levels, groundwater flow patterns, recharge and discharge (considered to be the major components of 'groundwater hydrology'), from the major aquifer units within the SREBA area.

Table 1 of the 2021 SREBA Water Quality and Quantity studies (Project 1) reviewed and summarised gaps in the information considered to be "essential to establish a pre-development baseline assessment for each of the main Cambrian and Neoproterozoic aquifers" (Northern Territory Government, 2021). This report identified that groundwater monitoring coverage was variable throughout the different regions and aquifers of the SREBA, with significant gaps in data for the Anthony Lagoon Formation, Antrim Plateau Basalt (Kalkarindji Suite) and Neoproterozoic Sandstones. The 2021 review table (reproduced below) also noted that there was a 'poor' understanding of inter-aquifer connectivity across all of these units and the Gum Ridge Formation, and 'moderate' to 'poor' understanding of aquifer hydrogeological parameters in these units. Below, we thus analyse whether subsequent SREBA data collection and monitoring infrastructure have since addressed these gaps.

Topic	Anthony Lagoon Formation	Gum Ridge Formation	Basalt	Neoproterozoic sandstones
Water level network	MODERATE	GOOD	POOR	POOR
Water quality network	MODERATE	GOOD	POOR	POOR
Aquifer connectivity	POOR	POOR	POOR	POOR
Aquifer extent and thickness	MODERATE	GOOD	MODERATE	POOR
Aquifer parameters	MODERATE	MODERATE	MODERATE	POOR
Recharge and discharge processes	POOR	GOOD	POOR	POOR

Table 1: State of knowledge (as of 2021) for baseline characterisation of groundwater and aquifer characteristics (Northern Territory Government, 2021).

[3]Note that a detailed analysis of surface water is not included within the scope of the current review; the primary focus is groundwater, in line with the authors' expertise.

Groundwater level data

Amery and Tickell (2022) present analysis of groundwater level data from 165 locations across the Cambrian Limestone Aquifer (the main shallow water supply aquifer above the Beetaloo sub-Basin), which they use to create new maps of groundwater potentiometric surface (elevation) and depth to water. Further hydrogeological data, including groundwater level monitoring, are presented in Tickell (2022), which focusses on analysing connectivity between the Anthony Lagoon and Gum Ridge formations (the two major aquifers in the CLA within the Georgina Basin).

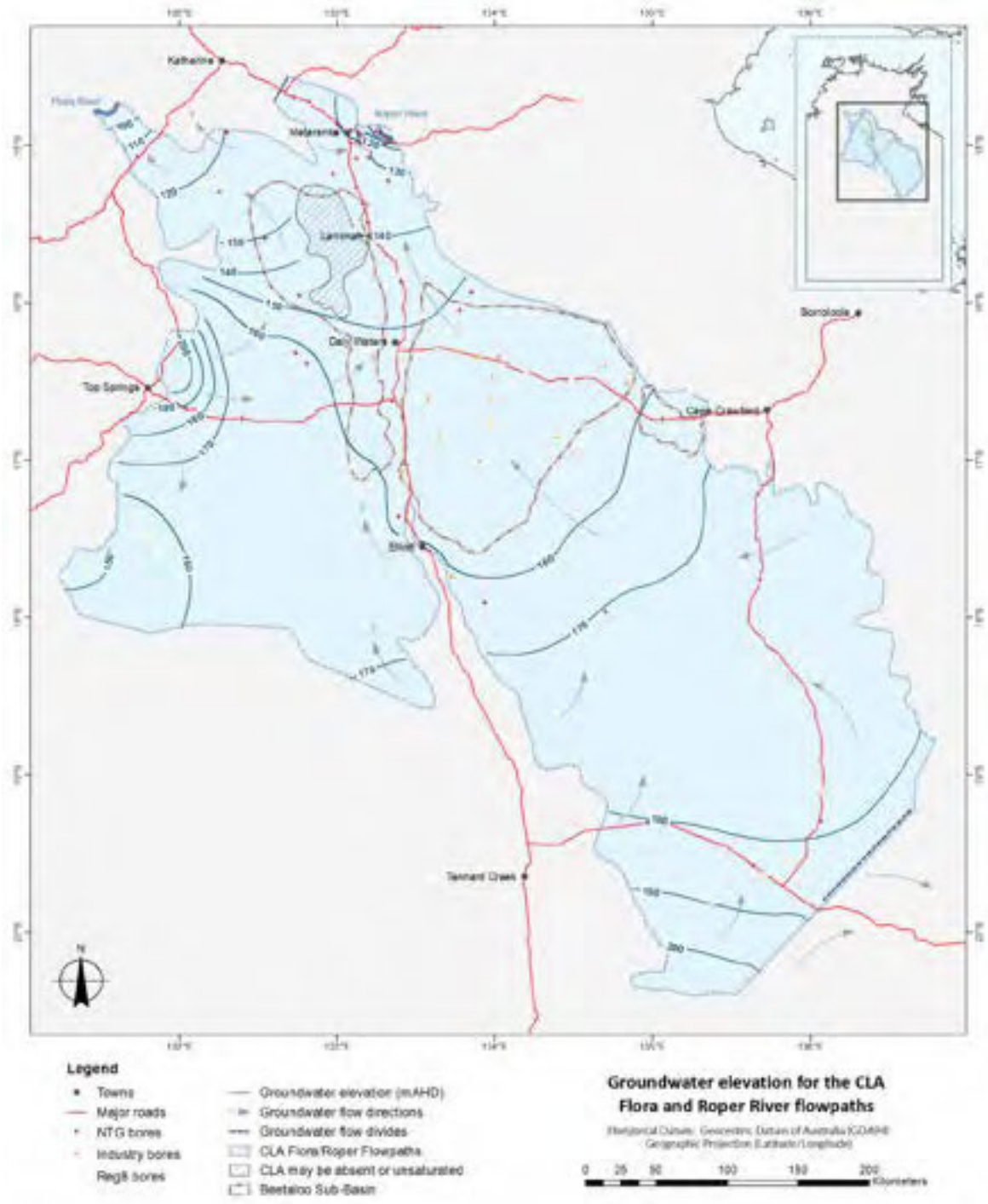


Figure 1 – New groundwater elevation map for CLA (Amery and Tickell, 2022) indicating density of groundwater level data points.

The new maps presented in Amery and Tickell (2022) provide reasonably good coverage of groundwater level measurements within the Cambrian Limestone Aquifer (CLA); however, they include regions with higher and lower density of data points (Figure 1). For example, water level data in the southern Wiso basin (near Elliot), southern Georgina basin (near Tennant Creek), and near the western edge of the SREBA area (e.g., near Top Springs) are very limited – leading to uncertainty as to the detailed groundwater flow paths in these areas (Amery and Tickell, 2022).

New bores in aquifers with previously limited water level data

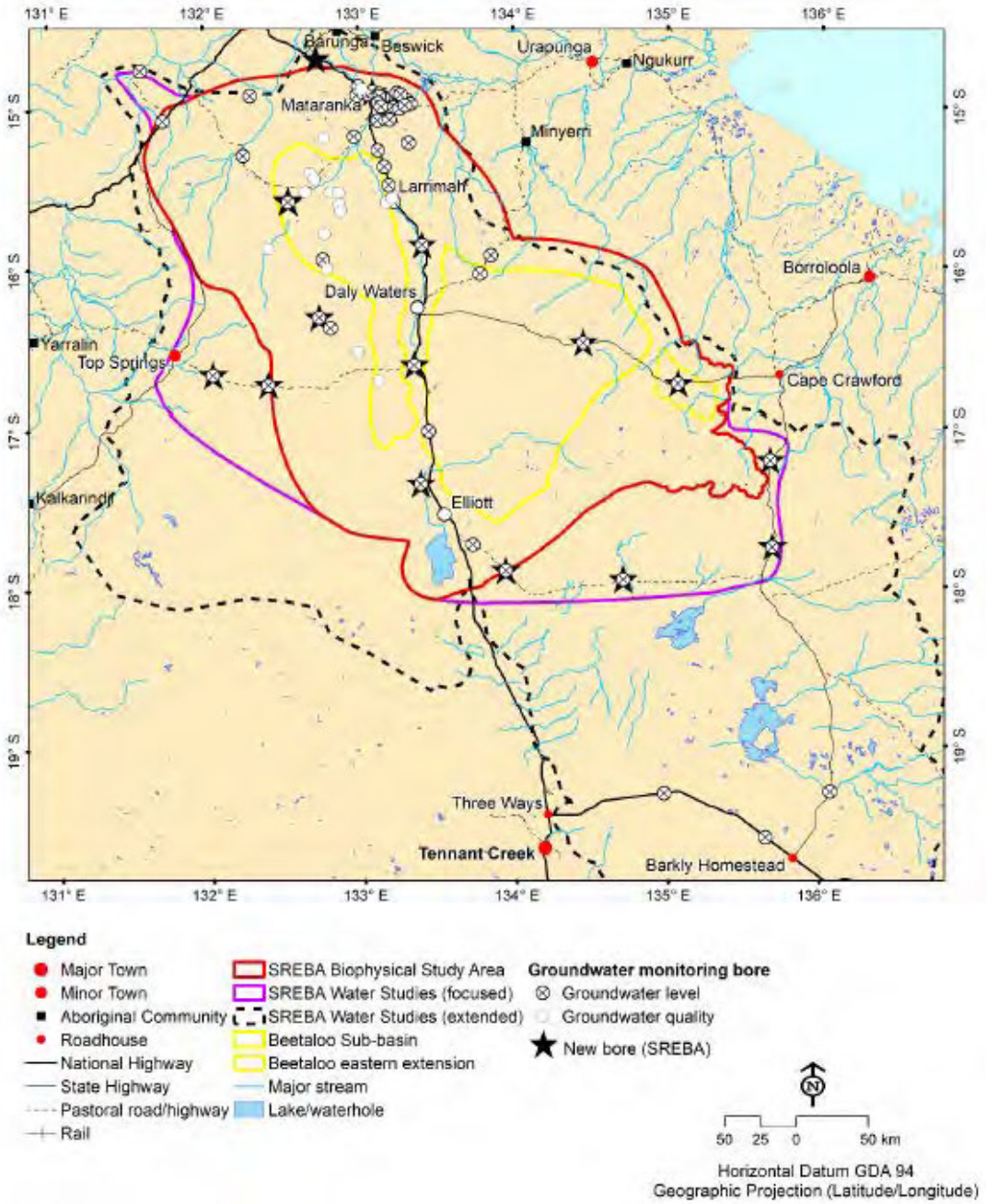


Figure 2 – New monitoring bores drilled specifically for SREBA water studies (ELA, 2022).

In order to obtain groundwater level data for geological units where existing baseline data were previously lacking (see Table 1), new groundwater monitoring bores in these units are required, and level data must be collected for a sufficient period of time to characterise temporal variability (i.e., change over time in response to climate and

other factors). The drilling of some new bores specifically for groundwater level and quality monitoring (and a small number of pumping tests) is outlined in ELA (2022), which notes that 23 new bores were drilled for the SREBA water studies. Sixteen of these bores are in CLA units, while two new bores targeted the Kalkarindji Suite/Antrim Plateau Basalt, and three in the Neoproterozoic Bukalara Sandstone (all at one locality). Above the CLA, two new bores were also constructed in the shallow Cretaceous sandstone. New bore locations are shown in Figure 2.

Assessment of the extent to which the new drilling and monitoring data have addressed the knowledge gaps outlined in in Table 1 for the major hydrogeological units is briefly summarised below:

Anthony Lagoon Formation: Groundwater monitoring coverage and baseline data for the Anthony Lagoon Formation was determined to be 'moderate' in the 2021 SREBA Project review (Table 1). Amery (2022) reports construction of three new monitoring bores in the unit, while Amery and Tickell (2022) indicate that six bores used to create the new groundwater surface maps are dedicated monitoring bores from this formation. This compares to more than 30 dedicated monitoring bores in each of the Gum Ridge Formation, Tindall Limestone and Montijenni Limestone. There are also a considerable number of bores – mostly constructed by industry for monitoring groundwater for gas exploration activities – where water level data have been utilised in the mapping, listed as 'ALF/GRF'. This is interpreted as screening both the Anthony Lagoon and Gum Ridge formations (although this has not been confirmed). Whether these bores are appropriate for baseline monitoring of water level trends over time (or whether this is feasible) depends on bore construction, the degree of connection between the two units in these areas, and the willingness of industry to provide data and/or access to the infrastructure. It is difficult to say whether there has been a significant improvement in monitoring bore and baseline water level data coverage for the Anthony Lagoon Formation until this is confirmed.

Hydrographs presented in Tickell, (2022) indicate that there are five nested pairs of bores which together monitor water levels in the Anthony Lagoon Formation and underlying Gum Ridge Formation. These nested bore pairs are located along a west-east transect within the Georgina Basin. These sites provide baseline data timeseries that are a reliable indication of groundwater levels in each unit, and to some degree, the level of connectivity between them – although as discussed below, the time period in which data have been collected is short in all but one of the pairs. Nested sites cover a relatively limited spatial area within a very large aquifer system. Further nested bores across the upper and lower CLA units - as well as those targeting the deeper aquifers – see below) are a critical requirement for fully understanding groundwater flow gradients, aquifer responses to climate, and inter-aquifer connectivity.

Antrim Plateau Volcanics (Kalkarindji Suite): Two new bores have been drilled within this lower Cambrian unit (below the CLA), both located in Elsey National Park in the Daly Basin (to the north of where Beetaloo basin rocks underlie the Cambrian and Neoproterozoic units). Monitoring bore coverage in this unit elsewhere throughout the SREBA remains limited. It is noted in the SREBA regional study that "where it (i.e., the volcanics unit) is absent, there is potential for direct connection between the deeper

Neoproterozoic or Mesoproterozoic aquifers…and the CLA." (DEWPS, 2022). Geophysical data – e.g., airborne magnetic surveys, also suggest areas where the volcanic sheet contains significant gaps, likely due to erosional processes after its deposition (Foss and Dhu, 2016). The volcanics unit is largely conceptualised as being an aquitard, although it is noted that in some places, water bores do access groundwater from the formation. Lamontagne et al., (2021) noted that groundwater discharge from this unit may be responsible for the observed isotope signatures in spring water from the Mataranka Springs complex, which indicate a deep source of water in addition to discharge from the Tindall Limestone. Monitoring bores within this unit are therefore an important requirement to understand inter-aquifer connectivity and groundwater discharge contributions - e.g., through water level monitoring and sampling for environmental tracer compositions.

Neoproterozoic Sandstones: There are a very limited number of bores in the Neoproterozoic sandstone aquifer units – e.g., Bukalara Sandstone, to address the identified gap in monitoring coverage and hydrogeological data for these rocks (Table 1). Tickell, (2022) discusses two bores in the Bukalara Sandstone which have monitored groundwater levels and quality below the Cambrian Limestone Aquifer, and which are paired with shallower CLA bores, enabling some analysis of connectivity. Short (2021) describes a drilling and pumping test program conducted during the SREBA for the Sturt Plateau. Three bores (all within close proximity) were drilled in the Bukalara Sandstone, beneath Wiso basin sediments. One was for pumping/production and two were for monitoring drawdown responses during a pumping test. This is one of the Bukalara monitoring sites mentioned in Tickell 2022; the other is at the bore Carpentaria 1 in the Georgina Basin. It is not clear whether there are any additional bores suitable for monitoring baseline groundwater levels in the Neoproterozoic rocks elsewhere in the SREBA area, despite it being noted that the Bukalara Sandstone is widespread and likely continuous throughout it. In some areas, this aquifer directly underlies the CLA, and may thus connect groundwater from deep Beetaloo sub-basin units and shallow aquifers (ELA, 2022). An additional 'Unnamed Sandstone' unit also lies between the Bukalara Sandstone (and Cox Formation, an aquitard which together with the Bukalara Sandstone forms the Kiana Group) and the overlying Cambrian rocks (DEPWS, 2022a and Tickell, 2022). Understanding groundwater level behaviour in this unit is also important to assess potential connectivity between deep and shallow aquifers. It is unclear whether any groundwater level monitoring bores were installed into this unit for the SREBA; it appears to remain another important gap in groundwater monitoring infrastructure / data coverage.

Temporal coverage of monitoring bores

A key aspect of the Pepper Inquiry recommendation(s) regarding groundwater hydrology/baseline data, is the need to characterise groundwater level and flow behaviour "over a period that is representative of the climatic cycles of the area". The temporal coverage of groundwater level monitoring data is therefore a critical consideration in assessing the adequacy of the SREBA groundwater baseline studies. Bores must have sufficient temporal coverage to be representative of both seasonal (within a year) and multi-year climatic behaviour (e.g., through drought and flood

periods). The data used to produce the new potentiometric surface and depth to water maps in the CLA (Amery and Tickell, 2022) were mostly collected from late 2018 into 2022. Data from Bureau of Meteorology (BOM) rainfall stations within the SREBA area over this period can be summarised as follows:

Daly Waters: Late 2018 to the end of 2021 includes one year with well below long-term average rainfall (2019), one year with well above average rainfall (2020) and one year that is close to the long-term mean (2021). Each of these years had pronounced dry and wet seasons.

Katherine: The period includes two years with rainfall below the long-term mean (2019 and 2020) and one year (2021) slightly above the long-term mean of 967.2mm.

Elliot: The period includes two below average rainfall years (including the lowest on record – 2019) and one year above the long-term mean (2020).

For these localities, which broadly cover the major climatic zones across the SREBA area, BOM rainfall data include a range of climatic conditions, broadly representative of wet and dry climatic states (although the northern area lacks a significantly above average rainfall year). Where groundwater level data have been continuously collected throughout this period, in a range of bores, this would serve as a reasonable baseline. It should be noted that there are times when rainfall during the wet season can be extremely high, e.g., associated with major cyclone systems (such as 1974) and that groundwater level behaviour during such periods is not well represented in the more recent baseline monitoring. Such periods are likely of great importance for groundwater recharge in the arid parts of the SREBA area; currently an understanding of associated recharge rates and processes is limited by lack of groundwater data from such periods (see Currell and Ndehedehe, 2022).

Hydrographs from CLA aquifer units within the SREBA area are presented in Appendix B of Amery and Tickell (2022). Many of these cover the baseline period noted above (late 2018 to early 2022), and some extend back considerably further in time (>15 years). However, there are other hydrographs that only commenced monitoring in 2020, meaning there are limited data representative of dry climatic conditions – the last below average rainfall year being 2019. The coverage of groundwater monitoring with time-series data representative of the region's variable climate is high for some areas – e.g., Mataranka and along the Barkly, Buchanan, and Carpentaria highways; however, coverage is limited in other, more remote areas of the SREBA. Most hydrographs contain water level data recorded using continuous loggers (which captures both short and long-term groundwater level responses); however, this only commenced recently (e.g., mid-2020) in many bores. In other bores, there are only a small number of manual water level readings, which give limited indication of responses to climate (e.g., RN038810, RN038810 at Larrimah, RN018206, RN018927 on the Barkly Highway, RN009304 at Elliot):

Of the nested upper/lower CLA paired monitoring bore sites mentioned above, which record water level timeseries in the Gum Ridge and Anthony Lagoon Formations (using data loggers), four have data collected from mid-2020 through to mid-2021 (a limited

snapshot with respect to climate variability), while one pair has data extending from late 2014 to 2022, which covers a wide range of seasons and climatic states.

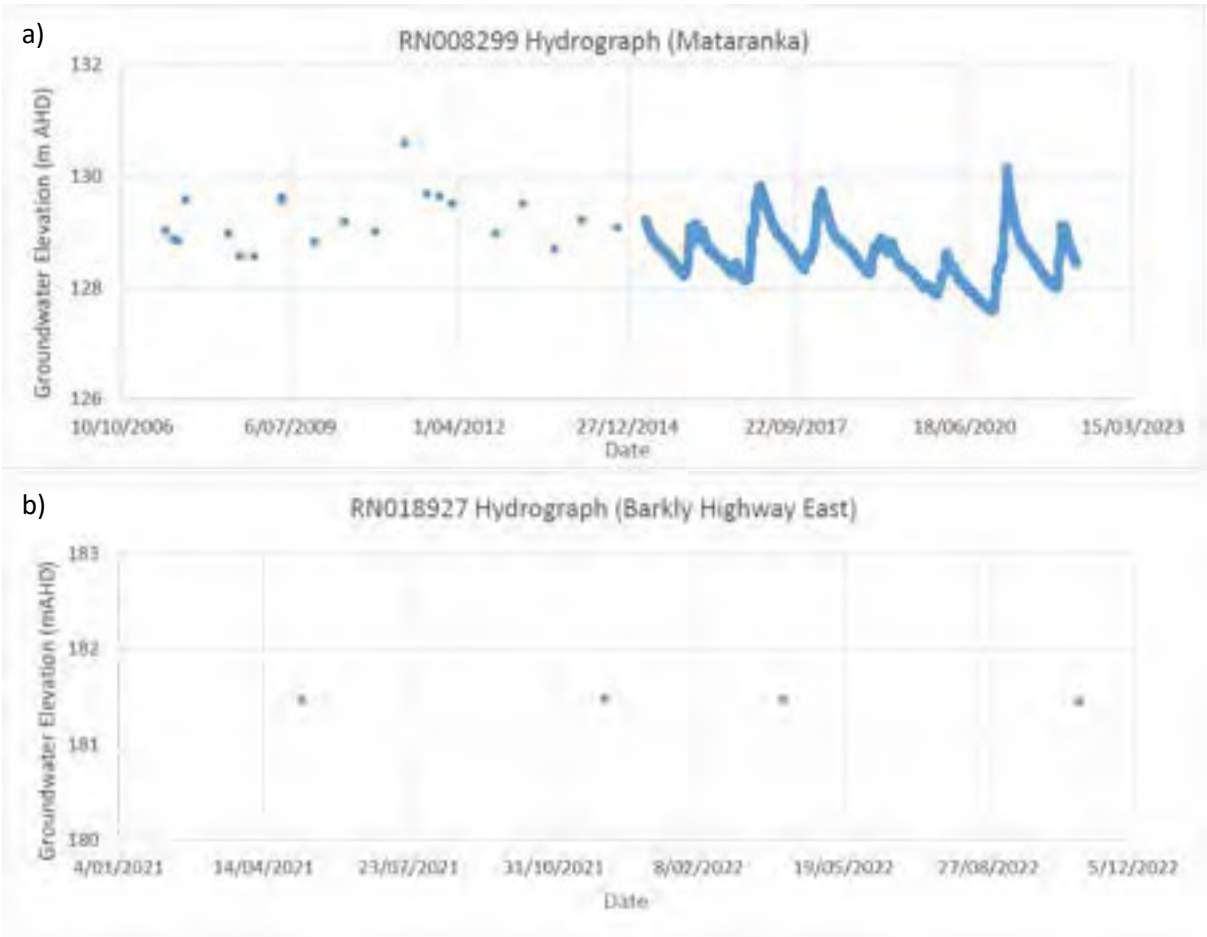


Figure 3 – Examples of monitoring bore hydrographs compiled by Amery and Tickell, 2022; a) Continuous time-series monitored with data logger (since 2015); b) small number of manual measurements, giving little indication of variability over time.

As mentioned above, there are few monitoring bores collecting data for more data-poor aquifers in the SREBA area (identified during the 2021 SREBA Project review - Table 1), i.e., the Antrim Plateau Volcanics and Neoproterozoic sandstone aquifers. Baseline data coverage in these units would therefore not meet the first objective of the SREBA water studies (SREBA Framework, 2020). A further issue is that there do not appear to be monitoring data collected from within the Mesoproterozoic Roper Group sediments – which are the rocks targeted by the gas industry - aside from some previously published data in Fulton and Knapton, (2015). This is important, as assessment of connectivity between target units for hydraulic fracturing and the overlying aquifers, requires analysis of vertical hydraulic gradients between these formations.

Table 3 summarises the status of baseline groundwater level data for the various regions and aquifers of the SREBA area:

Unit /Aquifer name	Monitoring bore spatial coverage	Temporal coverage (period monitored)	Comments

Tindall Limestone (CLA)	Generally good (although coverage appears to be relatively sparse between Daly Waters and Larrimah)	Good; some bores monitored > 10 years	Water level variation and flow paths are relatively well-characterised; this is an extensively utilised aquifer in the region surrounding Mataranka and Katherine. Coverage further south (e.g. near Larrimah) less extensive.
Gum Ridge Formation (CLA)	Good (though lacking near edges of Georgina Basin)	Most new monitoring bores recording data from late 2018 onwards; some longer records also available (>10 years data)	Flow patterns and baseline data at the western Georgina basin boundary (Daly Waters) and southern basin (north of Tennant Creek) poorly understood, due to lack of monitoring bores. Coverage is better through central areas of the basin, including above Beetaloo sub-basin.
Anthony Lagoon Formation (CLA)	Moderate	New bores mostly installed in 2020-21; time-series data limited	Additional bores within the ALF/GRF have been installed, mostly by industry. Number of dedicated monitoring bores (as opposed to those screening both CLA units) is unclear. Temporal coverage in most bores relatively limited (compared to other CLA units).
Montijenni Limestone (CLA)	Good (although limited in western Wiso Basin)	Appears to be good in NT government monitoring bores; although number of these bores limited in some areas, e.g., edges of Wiso basin	Connectivity with groundwater flowpath(s) in the Georgina Basin (across eastern Wiso Basin boundary) not well understood.
Kalkarindji suite basalt (Antrim Plateau Volcanics):	Poor	Very limited	Monitoring bores are generally lacking; two additional bores constructed for SREBA.

Below CLA / above Beetaloo sub-basin.			
Un-named Sandstone unit: Below CLA / above Beetaloo basin	Poor	Very limited	Monitoring bores (completely?) lacking
Bukalara Sandstone (Kiana Group) Below Kalkarindji suite / above Beetaloo basin	Poor	Very limited	Monitoring bores generally lacking. Tickell (2022) notes two localities with monitoring bores in the unit and overlying CLA which enable assessment of connectivity. Short (2021) describes drilling a site with three bores for pumping test analysis.
Roper Group (Beetaloo Basin, target for shale gas)	Poor	Very limited	Monitoring bores lacking – unclear if there are plans to address this gap. While there are no water supply aquifers in these rocks, it is important to understand water levels and quality to enable future impact assessment in overlying aquifers.

Table 3: Summary of groundwater monitoring bore coverage for different units within the SREBA.

Groundwater flow paths and discharge to surface water

Three major flow paths within the CLA have been defined through groundwater investigations over the past ~20 years; Roper, Flora and King-Roper. These have been mapped in more detail through the data collected and compiled for the SREBA (Amery and Tickell, 2022). The major groundwater discharge areas for these flow paths are known – Roper River, Flora River, and Mataranka Springs; however, other discharge areas are not as well-characterised (see below).

Discharge of groundwater to the Roper River and Flora River has been quantified through past studies (e.g., Karp, 1997 & 2008); however, there are uncertainties regarding the source(s) and timescale(s) of flows to the surface via springs (see Lamontagne et al., 2021 and further discussion below), and the SREBA studies do not appear to have significantly addressed these uncertainties, such as the extent of flow contribution from deep units below the CLA to Mataranka and Flora River springs. Tracer studies to identify origins of water and timescales of flow to the Flora River springs are lacking in part due to limitations encountered in a CDU study on this topic (commissioned for the SREBA; Irvine and Duvert, 2022).

Further areas of groundwater discharge within the SREBA have been identified, notably Top Springs (western Wiso Basin) and Hot Springs Valley (eastern Georgina Basin – see Figure 4-21 of the SREBA Regional Report, DEPWS, 2022a). The flow-paths, source aquifer(s) and timescales of flow to these areas remain poorly understood, and they have not been fully integrated into an understanding of groundwater flow paths and inter-aquifer connectivity. Regarding Top Springs, Tickell, (2022) noted that:

> "Several small springs discharge from the Lower CLA on the western margin of the Wiso Basin. These include Lonely Spring and Palm Spring. The source of several other springs; Old Top Spring, Illawarra Spring, Killarney Spring and Top Spring located in the same general area is not yet established however they are likely fed from a limestone and chert unit that is interbedded in the Kalkarindji Suite basalt…It is also possible that the Lower CLA is the source (or the partial source) for those springs."

> "In the Top Springs area a groundwater mound is present, indicating basin-wards flow to the east. The mound is relatively steep which reflects thinning of the aquifer along the western margin. There is some indication that the eastward flow turns to the north east in the vicinity of Daly Waters and possibly crosses into the Roper River flowpath. Some minor westwards flow must occur around Top Springs because Lonely Spring and possibly a few other small springs discharge from the Montejinni Limestone."

> "On the far south-western side flow is from east to west, toward the basin margin. To date no springs have been recorded in that area but it is worthy of closer investigation."

These observations highlight ongoing uncertainty regarding source aquifer(s), flow paths and discharge rates for these springs. A further uncertainty critical to assessment of the SREBA area's water balance and hydrogeological processes, is the mechanism(s) by which regional-scale groundwater flows leave the CLA. The SREBA analysis (DEPWSa, 2022; Tickell, 2022) concludes that much of the discharge to the Flora and Roper rivers probably originates from recharge relatively close to the rivers, rather than from regional flows integrating recharge over large spatial scales. If this is the case, it remains unclear where the rest of the groundwater recharged into the CLA ultimately discharges (e.g., through cross-aquifer flow, diffuse ET by vegetation, or other un-characterised discharge features). Discharge of a more regional and/or deeper flow component appears to be indicated by preliminary tracer data from springs (Lamontagne et al., 2021; Irvine and Duvert, 2022), but this is not well understood.

Another important area of considerable groundwater discharge within the SREBA area (above the Beetaloo sub-basin) is Hot Springs Valley in the Georgina Basin, which was visited during a late stage of the SREBA water studies. Groundwater discharges from these springs at considerable rates (e.g,, Tickell, 2022 estimated flows of approximately 30 to 40 L/s for two springs) and the source of water is likely to be one or more deep aquifers, consistent with high temperatures (DEPWS, 2022a). However,

the origins of the spring water, timescales of flow, variability in flows and/or chemistry over time, and connectivity with regional/local groundwater flow paths, are all uncertain. The current lack of groundwater data from units below the CLA – such as the Kalkarindji Suite, Bukalara Sandstone, and other Proterozoic aquifers (See Table 1 and 2), and a lack of nested monitoring bores targeting deep and shallow aquifers together, means that these questions cannot be addressed at present. This is a critical knowledge gap in the context of potential shale gas development, as a deep source of groundwater discharge may be particularly susceptible to impacts from hydraulic fracturing (e.g., targeting the deep Proterozoic rocks of the Beetaloo sub-Basin).

Groundwater throughflow

The SREBA groundwater studies conclude that regional groundwater through-flow between the Georgina and Wiso Basins into the Daly Basin (along the Roper and Flora flow paths) is a relatively minor component of the overall water balance, in comparison to localised/nearby recharge. Estimates of throughflow have varied among different studies – e.g. Tickell and Bruwer, 2015; Knapton, 2020 and the SREBA water resource assessments. The estimates of throughflow should be seen in the context of a lack of full accounting for discharge sources, rates and areas (see above). There is also remaining uncertainty regarding cross-flow between the Flora and Roper flow paths in the vicinity of the junction of the three CLA sub-basins (near Daly Waters). This has implications for the water budget, including the degree of throughflow previously estimated in the water resource assessments for the different regions:

> "The pattern of groundwater flow is known on a broad scale but in some areas there is significant uncertainty due to wide gaps in the monitoring network. Particular areas that would be useful to investigate include the current north-south flow boundary between the Flora and Roper flow paths. There are indications that in the vicinity of Daly Waters there is flow from the Wiso Basin to the Georgina Basin. If correct, then the boundary between the two flow paths may need to be adjusted which would affect the water balances of the respective Water Allocation Plan areas." (Tickell, 2022).

In summary, while the SREBA studies have helped to characterise baseline groundwater levels and flow paths within large areas within the CLA, there remain considerable gaps in the data and knowledge relating to the first objective of the SREBA water studies (SREBA Framework, 2020). These include:

- A lack of monitoring bores, including nested sites, to characterise the groundwater level behaviour and flow gradients in the aquifer units below the CLA - e.g., Neoproterozoic sandstones, Kalkarindji Suite Volcanics, and Mesoproterozoic formations (potential targets for shale gas development).

- Areas where CLA groundwater levels and flow paths remain relatively poorly known -such as at the edges of the Wiso and Georgina Basins, and above the Daly Waters high.

- Limited understanding of the flow paths and water sources to key groundwater discharge features in the SREBA area (e.g., Top Springs and Hot Springs Valley)

and the rates and mechanisms of groundwater discharge to these and other discharge features – e.g., Flora River springs.

Objective 2: "Characterise the hydrostratigraphy of the region sufficient to identify and characterise the aquifer systems and any interconnectivity that could be affected by the extraction of water for any onshore shale gas development."

Connectivity between different aquifers, and between shallow groundwater and the surface environment, is a vital component of assessing the impacts and risks associated with increased extraction of groundwater and/or hydrocarbons from sedimentary basins (Jackson et al., 2013a; Jackson et al., 2013b; Scientific Inquiry into Hydraulic Fracturing in the NT, 2018). This section explores the extent to which the SREBA studies have generated understanding of the level of connectivity within and between the hydrogeological units in the SREBA area, inline with the Pepper Inquiry's recommendations.

Connectivity within the CLA

Tickell (2022) examined the issue of Intra- and Inter-aquifer connectivity for the major aquifer units, including the upper and lower CLA (major water supply aquifer for the region), and units below – Antrim Plateau Volcanics (Kalkarindji Suite), Neoproterozoic sedimentary rocks, and Mesoproterozoic Beetaloo sub-basin rocks. The analysis is based on geology, geophysics, hydrochemistry and water level data, much of which pre-dates the SREBA studies - e.g., work conducted for the Bioregional Assessment (GBA) or GISERA studies, but which has been further supplemented by some additional datasets and analysis commissioned for the SREBA.

The Tickell (2022) report and ELA (2022) conclude that while there is considerable evidence of separation between the upper and lower CLA in the northern part of the SREBA (the Daly Basin), elsewhere – such as in the Georgina Basin, the CLA behaves as a large, hydraulically inter-connected aquifer system, mostly semi-confined below Cretaceous cover. One of the final recommendations in Tickell (2022) is that despite the evidence of connectivity between the upper and lower CLA aquifers, the two sub-units should 'continue to be treated as not being hydraulically connected and separate resources.' This is largely related to risk management; in the absence of comprehensive local-scale understanding of connectivity throughout the aquifer system, new production bores that ignore potential separation between the two units may act to create pathways for greater connectivity than currently exists.

For the purposes of assessing potential long-term impacts of increased extraction of water from the SREBA area, evidence of strong hydraulic connection between the Upper and Lower CLA units in key areas (such as the Georgina Basin) must be carefully considered. This is critical to ensuring pathways for propagation of drawdown from deeper to shallower levels (or vice-versa) - which may affect groundwater discharge to the surface - are incorporated into risk assessments for increased water extraction from the CLA. It remains unclear the extent to which evidence of inter-aquifer connectivity between the two CLA units described in Tickell (2022) has been

reflected in numerical modelling of the groundwater system – such modelling appears not been substantially revised or updated since the reporting by Knapton (2020).

Pumping tests in the various Cambrian Limestone Aquifer units have been conducted in different areas of the SREBA, mostly through hydrogeological investigation programs conducted prior to SREBA studies. Data from more than 150 such tests have been compiled in DEPWS (2022b) and Amery (2022). These studies identify the range of transmissivity and storativity values for the aquifers, which set the upper and lower boundaries for appropriate parameters to model CLA groundwater. The coverage of these tests (like the baseline groundwater level data) is higher in certain regions and lower in others e.g., the Wiso Basin (Figure 4).

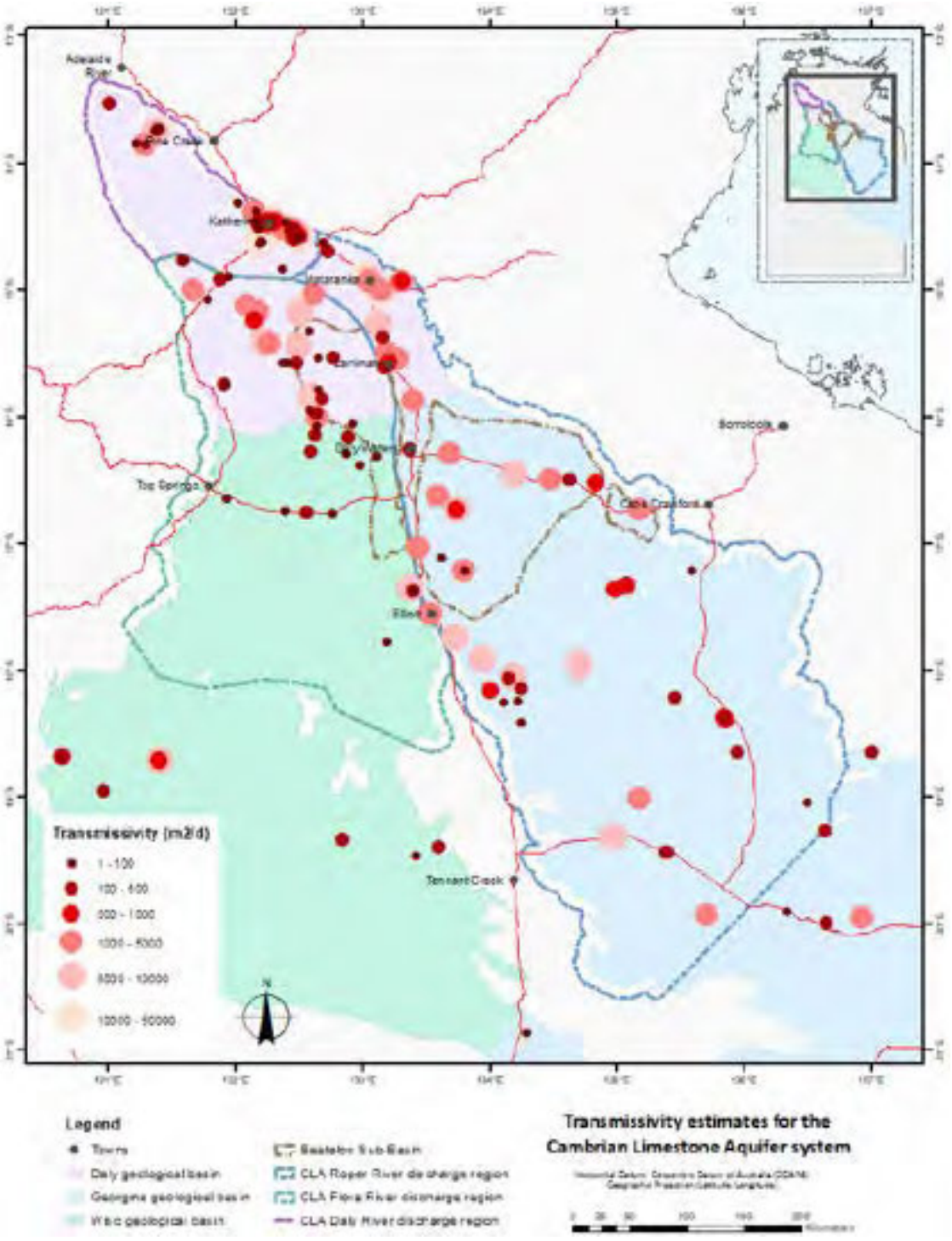


Figure 4 – Map showing coverage of bores from which aquifer test data (transmissivity) are available (Amery, 2022).

Shallow-Deep aquifer connectivity

Available data to inform the question of connectivity between the shallow CLA aquifers and deeper hydrogeological units of the SREBA area (e.g. lower Cambrian volcanic rocks, Neoproterozoic sandstones and Mesoproterozoic Beetaloo Basin units) are limited. Field data to understand inter-aquifer connectivity across the geological sequence remains localised to some areas where there has been deep drilling and characterisation of stratigraphy, a handful of bore pairs monitoring the CLA and underlying Neoproterozoic sandstone (including one pumping test to assess connectivity), and some limited environmental tracer and geophysics data from springs and certain bores, mostly collected during GBA or GISERA studies (e.g. Lamontagne et al., 2021; Frery et al., 2022). The understanding of deep-shallow aquifer connectivity does not appear to have significantly advanced beyond the analysis completed for the GBA (Evans et al., 2020), who noted that there are five potential pathways of inter-aquifer connectivity, but that "The degree of inter-aquifer connectivity is not well characterised." The GBA study published by Frery et al (2022) contained some additional analysis of connectivity associated with fault zones based on geophysics and tracer data which is valuable (see below), but the authors also highlighted that their work provided only preliminary evidence of deep-shallow connectivity, and that significant additional data are needed to understand connectivity comprehensively. This is critical to successful achievement of the SREBA Framework objective, including robust assessments of risks of groundwater leakage and contaminant migration associated with unconventional gas activities.

As noted in Tickell (2022), an understanding of connectivity between the deep and shallow units of the SREBA area requires construction and testing (e.g., using hydrochemical tracer data and pumping test analysis), of nested groundwater monitoring bores tapping the various units at different depths:

> "Knowledge about connectivity between the CLA and deeper aquifers is based on subsurface geological relationships determined by deep drilling, geophysical surveys and detection of ^{3}He in groundwater. Surfaces of key layers have been generated by Frogtech Geoscience (2018b & 2018a) and more recently by GBA (2019). These were used by Evans et al. (2020) to identify areas where the CLA is in contact with deeper aquifers. Information on vertical pressure gradients between the CLA and deeper formations in the Roper and Kiana Groups was compiled by Fulton and Knapton, (2015). Although data was only available from four petroleum wells there was an upward pressure gradient in each well, indicating the potential for upward movement of groundwater. To date, there are only two sites (Carpentaria 1 and Larrizona shown on Figure 20) where bores have been drilled in these areas to monitor groundwater levels and water chemistry in both the CLA and the underlying aquifer."

It should be stressed that the mapping of areas of potential deep-shallow aquifer connectivity (e.g. Figure 4 of Tickell, 2022) is based on a small number of deep bores, and there remains considerable uncertainty as to the extent, thickness and hydraulic properties of the deep aquifer units and intervening aquitards below the CLA, down to the Beetaloo basin rocks, and presence / absence of geological structures. A program of geological, geophysical and geochemical investigations (e.g., encompassing deep drilling and rock/sediment analysis, seismic and electromagnetic surveys, isotopic and hydrochemical vertical profiling and vertical head gradient analysis) is required to resolve this.

Key aspects of inter-aquifer connectivity relative to impact assessment

The lower Cambrian Antrim Plateau Volcanics / Kalkarindji Suite are largely conceptualised in the SREBA reporting (and GBA studies) as a regional-scale aquitard. The unit sits between the Beetaloo basin rocks and shallower CLA aquifer(s) and is considered likely to limit the potential for connectivity between these systems (DEPWS, 2022a). However, it is also noted in some of the SREBA material that the basalts are locally utilised for water supply, and they are not laterally continuous across the region (e.g., Figure 2 of Tickell, 2022; Foss and Dhu, 2016). The potential for significant groundwater discharge from the unit on the margin of the Wiso Basin was also noted (DEPWS, 2022). Further investigation of the extent and thickness of the basalts, their lithological properties, and how this might affect connectivity with units above and below is thus an important aspect of meeting Objective 2. Such analysis could be conducted by means of further logging of bores in data-poor areas and pumping tests and/or tracer studies targeting the basalts and units above and below. The hydrogeological behaviour of this unit is critically important to assessing inter-aquifer connectivity and associated risk from water and/or gas extraction, due to its position between the Beetaloo basin and younger Cambrian aquifers.

The other major units between the deep Beetaloo basin rocks and the CLA include the Bukalara Sandstone and Cox Formation (Kiana Group) and an un-named Neoproterozoic sandstone that has recently been identified during deep bore drilling in the area. The extent, thickness and lithology of these units is not well understood, other than having been mapped to some extent below the Daly and northern Georgina basins (see Figure 4 of Tickell, 2022). Tickell (2022) notes that there are areas where the Neoproterozoic sandstones and CLA aquifers are in direct connection, providing a potential pathway for deep-shallow groundwater connectivity:

> "Only two formations: the unnamed sandstone (Altmann et al 2020) and the Bukalara Sandstone can be considered to be mappable aquifers. The former has mostly been identified beneath the Kalkarindji Suite. One exception is at the well Tanumbirini 1 where it is in direct contact with the CLA. Bukalara Sandstone occurs in three windows directly beneath the CLA. The first is centred on Elliott 1. A smaller area is south-east of Tanumbirini 1 and the third occurrence is in the eastern-most outlier of the Beetaloo Sub-basin area, intersected in the water monitoring bores for Carpentaria 1 and 2."

Two sites include bores constructed specifically to examine connectivity between the Bukalara Sandstone and overlying CLA for the SREBA (Short, 2021; Tickell, 2022). These provide an indication of the thickness and lithological properties of the units, as well as deep-shallow connectivity at these two localities (a very limited number given the size of the SREBA area and significance of the aquifer connectivity issue):

> "Two of the sites with paired bores have been constructed for monitoring the Lower CLA and the underlying Bukalara Sandstone and equivalents. The first is at Larrizona Station (Western Creek Road) where the Lower CLA is separated from the unnamed sandstone and Bukalara Sandstone by over 120 m of basalt (Short, 2021). The other is at the Carpentaria 1 site where the Lower CLA directly overlies the Bukalara Sandstone."

The investigation work of Short (2021) shows that connectivity is limited at the first of these sites, while Tickell (2022) notes that the other site where bores occur in both units, shows strong indications of connectivity:

> "At the Carpentaria 1 location, groundwaters in both aquifers are magnesium bicarbonate types (Figure 27) and have comparable TDS values. The Lower CLA has a TDS of 686 mg/L and the Bukalara Sandstone is 576 mg/L. That difference is due to higher calcium and bicarbonate concentrations in the CLA. These observations indicate that the two formations have good hydraulic connection. Similar water levels measured in both formations support that conclusion."

Connectivity between groundwater from deep, Proterozoic rocks and the shallow aquifer system in the eastern part of the SREBA (Tanumbirini station) is consistent with a deep source of groundwater sustaining the spring flows within Hot Springs Valley. Gaining a better understanding of the extent of this zone of connectivity, the hydraulic properties of the units, and the likely rates of leakage between the aquifers in response to groundwater extraction is critical to meeting the SREBA Objectives, but this is unresolved at the current time.

The SREBA regional report (DEPWS, 2022a) also notes that there is an area – the Daly Waters High – where both the lower Cambrian basalts, and Neoproterozoic rocks are absent, meaning the Beetaloo basin rocks (targets for shale gas development) may be directly in contact with the CLA. It also does not appear that inter-basin connectivity in this region has been assessed in any detail. This would require the installation of nested monitoring bores targeting the Beetaloo basin rocks, and overlying CLA unit(s), analysis of water level trends, hydraulic testing, and environmental tracer sampling.

Hydraulic testing

As discussed above, there have been a considerable number of pumping tests conducted within CLA bores (albeit with data coverage greater in some parts of the SREBA area than others – see Figure 4). However, pumping tests which target deeper aquifers below the CLA, to inform analysis of inter-aquifer connectivity between deep and shallow aquifers, are very limited. One pumping test was specifically commissioned for the SREBA (Short, 2021). This indicated limited connectivity

between the CLA and Neoproterozoic sandstone (comprising the Bukalara and Unnamed sandstone described above) at the locality, during a four-day constant rate test. Testing for a longer period of time (e.g. >7 days) and with additional monitoring bores in the intervening Antrim Plateau Volcanics, and similar pumping tests at other localities, would be needed to further constrain whether significant leakage is likely to occur in response to pumping from the aquifer in the long-term and on a regional scale.

The testing described in Short (2021) and the second site at Carpentaria-1 are local scale studies which highlight that both the stratigraphy (e.g., thickness and extent of the Neoproterozoic sandstone units) and their hydraulic properties – e.g., connectivity between these units and the CLA above – are variable in different parts of the SREBA area, and this has only recently begun to be characterised. Understanding whether such connectivity is more extensive in other areas – e.g., where the intervening basalts are thin or absent, or where geological structures may enhance connectivity (as demonstrated in Frery et al., 2022), requires additional drilling and pumping tests, supplemented with other lines of evidence (e.g. geophysics and geochemical data).

Geophysics and Environmental Tracer data

The analysis of seismic, remote sensing, gravity, airborne electromagnetic and gamma log data (i.e., geophysics) together with geological logs, is an important part of characterising geological structures that may impact on inter-aquifer connectivity at local and regional scales. Environmental tracers - such as isotopes of helium, strontium and other radioisotopes in groundwater, also provide important evidence that can identify areas of deep-shallow aquifer connection. Analysis of high-resolution topography and geomorphology is also an important aspect of such studies – e.g., Frery et al., (2022) noted that surface drainage patterns above the OT Downs fault zone are influenced by the underlying geological structure(s).

Faulting was identified in the GBA studies (Evans et al., 2020) as a key potential pathway for connectivity between deep and shallow aquifers in the region, and investigations using geophysics and tracers were conducted by Frery et al., (2022). The coverage of seismic and other geophysical data to map out the extent and depth of fault zones, along with environmental tracer data from springs and bores, to identify pathways and extent of deep fluid flow to shallow depths, are still very limited. Based on the combination of geophysics and tracer data available currently, Tickell (2022) concluded:

> "The datasets described above were all used to define five areas where there is higher potential for connectivity along faults. These include the OT Downs Fault Zone, the Mataranka Springs Complex (north Birdum Creek Fault area), the central part of the western Beetaloo Sub-basin, the Elliott area and the central part of the eastern sub-basin. The only known examples of water moving along a fault from a considerable depth are hot springs associate with the OT Downs Fault Zone." (i.e., Hot Springs Valley).

Further,

> "Two hot springs on Tanumbirini Station were visited by Zaar (2009) along Beauty Creek and Lagoon Creek, northwest flowing tributaries of the upper Cox River. Both streams are likely to follow major faults that are part of the OT Downs Fault Zone. The spring on Beauty Creek (Water Resources Division site number G9055086) had a temperature greater than 60˚C and an estimated discharge of 30 L/s. The spring on Lagoon Creek (G9055076) had an estimated discharge of 20 L/s but the temperature was not measured. A second visit took place in September 2022 (Zaar and Tickell, 2022) and G9055086 and another spring on Gorge Creek (not G9055076) were visited. Estimated discharges and selected water quality parameters of the three springs are listed in (Table 5) This series of springs was identified during the GBA program (Evans et al. 2020) as an area of interest for the Beetaloo Sub-basin because the outcropping formations in the area and the likely groundwater source for these springs are the deep Mesoproterozoic formations that are part of the gas resource sequence."

Environmental tracer data (particularly helium) from Mataranka Springs (Lamontagne et al., 2021) and Hot Springs Valley (Frery et al., 2022) indicate a deep water source contributing to spring flow in both of these important groundwater discharge areas:

> "High concentrations of radiogenic 4He (> 10^{-7} cm^3 STP g^{-1}) at Rainbow Spring, Bitter Spring and in nearby groundwater also indicated an input of deeper, older groundwater. The presence of older groundwater within the CLA demonstrates the need for an appropriate baseline characterisation of the vertical exchange of groundwater in Beetaloo Sub-basin ahead of unconventional gas resource development." Lamontagne et al., (2021).

> "The noble gas helium, produced by natural decay of uranium and thorium in the aquifer and indicative of the input of old groundwater, was detected in several bores from the CLA and two springs, suggesting upward flow of old groundwater from deeper aquifers. The amount of this inflow cannot be quantified without knowing the helium concentration in those formations. No indication of mantle helium has been found in the Beetaloo Sub-basin. Additional research is required to understand the nature of the vertical connectivity demonstrated by helium". (Frery et al., 2022)

The analysis of tracer data still thus appears to be in the early stages of defining the source(s) of fluids at different depths in areas of potential inter-aquifer (and basin) connectivity. Some further data to inform analysis of the depth/source of water flowing to the Hot Springs Valley springs is noted as being in the process of being collected:

> "During the September 2022 site visit, samples for environmental tracers (helium, carbon-14, chlorine-36, tritium, strontium isotopes and stable water isotopes) were also collected from the main Beauty Creek Hot Spring vent to help identify potential source aquifers and discharge mechanisms. At the time of reporting, results of these tracers had not been provided by CSIRO to inform the development of this section. However, a member of the SREBA greenhouse gas baseline studies was present during the field visit, and they

recorded detectable and correlated concentrations of methane and ethane in the air surrounding the Beauty Creek Hot Spring vent when bubbles were noted to be emanating from the spring vent. This provides further evidence of a deep source, possibly associated with Beetaloo Sub-basin gas exploration targets." (Tickell, 2022).

A key issue to consider is whether extraction of groundwater and/or hydrocarbons may cause enhanced movement of groundwater along structure features/zones that facilitate enhanced permeability between deep and shallow geological units. While the above studies provide preliminary evidence of deep groundwater and/or gas flow reaching shallow aquifers and the surface environment, a full assessment of the extent of connectivity and likely behaviour of the springs and shallow aquifers in response to extraction of water and/or gas (as per the SREBA Framework objectives), will require substantial additional data and analysis (Frery et al., 2022).

Overall, the number of deep bores available to fully constrain the thickness, extent and lithological properties of the formations below the CLA and above the Beetaloo basin is small, and areas where connectivity has been further assessed through hydraulic testing, geophysics and environmental tracer data limited. Deep bores should be constructed through the full thickness the aquifer system, with logging of changes in multiple geophysical and water quality parameters with depth, followed by construction of a nested piezometer site tapping the aquifers at multiple depths. The analysis of tracers, geophysics and pumping tests, covering a range of localities, will be necessary to fully address the SREBA water studies objectives.

In summary, there remain critical data and knowledge gaps regarding the extent of inter-aquifer connectivity for key units that may be subject to water and/or gas extraction in the future:

- Additional nested monitoring bore sites are required to enable hydraulic and geochemical testing, to establish the level of inter-aquifer connectivity across the range of geological profiles within the SREBA region – in particular, between the Neoproterozoic and Mesoproterozoic units, and the overlying Cambrian aquifers.

- Regions where connectivity between the Beetaloo basin rocks and overlying Cambrian aquifer(s) may be considerable – such as the Daly Waters High and OT Downs sub-basin (near Hot Springs Valley) do not appear to have been extensively drilled or characterised (e.g. with tracer sampling, multiple geophysical techniques and hydraulic testing) to understand lithological profiles, groundwater level gradients and other potential indicators of vertical connectivity.

- Preliminary data (mostly from hydrochemical/environmental tracer sampling) indicate areas of substantial connectivity between deep aquifer units and the shallow CLA and/or springs, where groundwater discharge from deep units occurs. The extent of these areas, and the potential impacts of increased water (or hydrocarbon) extraction from different depths (e.g., on inter-aquifer leakage and spring discharge rates) have not been established.

Objective 3: "Quantify recharge rates (and where possible, recharge zones) and establish the sustainable yield for potentially affected aquifer systems."

Estimation of recharge rates for the aquifers of the SREBA region has been compiled from various previous studies, as outlined in Chapter 4 of the Regional Report (DEPWS, 2022a). This report details the four main recharge processes across the CLA, as well as mapping recharge potential at regional scale (shown in Fig. 4-20). Analysis of recharge rates and recharge areas for the major aquifers relies upon studies conducted through CSIRO and Geoscience Australia (the GBA program), along with numerical modelling conducted by the Water Resources Division of the Northern Territory Government (Knapton, 2020). The SREBA studies conducted limited additional field data collection to quantify recharge rates.

Recharge to groundwater occurs by a combination of diffuse recharge (spread across the landscape) and focussed recharge (associated with specific landscape features). Ranges of diffuse recharge rates across much of the SREBA area have been relatively well-constrained through chloride mass balance analysis, reported by Crosbie and Rachakonda (2021).

However, the range of overall recharge rate estimates derived from different sources and techniques (e.g., chloride mass balance and various modelling studies) is still wide. For example, low-end CLA recharge estimates for the CLA in the Georgina Basin are on the order of 100 GL/year, while the DR2 model and constrained chloride mass balance estimates are over 500 and 1000 GL/year, respectively (DEPWS, 2022c). This indicates considerable residual uncertainty in the estimated values.

Environmental tracer and other data indicate that recharge is likely to be highly preferential in many areas, as well as being strongly episodic - associated with short term periods of high rainfall, particularly in the more arid southern parts of the SREBA. These recharge mechanisms are not well quantified using chloride mass balance. The SREBA and GBA studies identified that recharge through sinkholes - large openings in limestone at or near the surface - is an important component of groundwater recharge to the CLA. Some new mapping of sinkholes has been conducted, to better constrain where these features may be contributing preferential recharge (Tickell, 2022; DEPWS, 2022a). Nonetheless, according to Tickell (2022), localised preferential recharge contributions remain poorly quantified, especially in southern CLA (i.e., above the Beetaloo sub-basin):

> "Various modelling techniques have determined recharge amounts on a regional scale, however contributions from individual recharge mechanisms on a more local scale have not been quantified." (Tickell, 2022).

Tickell 2022 and the other SREBA reports argue that the DR2 model is the most reliable estimator of recharge rates, and this is the approach taken to water balance estimation in the regional water resource reports produced under the SREBAr:

> "Of the data sources above, the DR2 Model is considered to be the most accurate in regard to the quantitative estimates of recharge rates across the region. This is because the model is tailor-made and based on the most up-to-

> date conceptualisation of the entire connected water resource (i.e., CLA and Roper and Daly Rivers), as well as calibrated to observed groundwater levels and river discharges. It is less powerful for predicting recharge locations and requires a prior understanding of the differences in recharge areas to be built into it. Recharge areas are described in Knapton (2020) but these areas are refined based on how well the model performs."

There are significant challenges with relying on numerical modelling as a tool in groundwater recharge estimation, in the absence of extensive field data to ground-truth recharge estimates and other model parameters (Sanford, 2002; Knowling and Werner, 2016).

Model-based recharge estimation, conducted by varying rates and locations (along with other unknown input parameters) and assessing calibration of the model's outputs against field observation data (e.g., groundwater levels and fluxes), suffers from the issue of non-uniqueness. This means that if multiple model parameters – such as recharge rates, hydraulic conductivity and storage coefficients - are all unknown or uncertain (e.g., due to a lack of sufficient field data), then the matching between modelled and observed data during calibration can be achieved through an infinite number of model parameter combinations, many of which may be far from representing the true aquifer characteristics and water balance inputs (Anderson et al., 2015; Knowling and Werner, 2016). The issue of non-uniqueness in model calibration becomes more and more pronounced as model complexity increases. A water balancing approach, using the DR2 numerical model, is adopted in the water resource reviews of the main sub-areas of the SREBA (DEPWS, 2022c; DEPWS, 2022d). In the Georgina Basin review, there is a large difference between mean and median recharge rate estimates derived from the modelling – consistent with highly episodic recharge – which is poorly documented or understood through field observations.

More generally, there is considerable variability in estimates of water balance terms (including recharge, discharge, and throughflow) derived from various iterations of modelling and field-based studies (see Currell and Ndehedehe, 2022). It appears that parameters such as the adopted storage coefficient(s) in the modelling, have a major effect on estimation of water balance terms:

> "The water balance includes the volume of water in storage, combined with the inputs (recharge, inflow) and outputs (outflow and ET from groundwater). The volume of groundwater storage presented in the water balance (667,480 GL) was determined for the CLA and overlying Cretaceous sediments. The model assumes a drainable porosity (or specific yield) of 0.04 (4%), which results in a storage volume that is significantly lower than the storage estimates presented by Tickell and Bruwer (2017) of 1,766,000 to 3,532,000 GL which mistakenly used specific yield estimates of 0.2 - 0.4 (20 - 40%)." (DEPWS, 2022a)

Verification of aquifer parameter values throughout the SREBA area (using field data) remains limited, particularly in data-poor regions (discussed above and highlighted in

Table 1). This creates a risk that model calibration alone results in highly uncertain estimates of recharge and other water balance terms. The significant differences in estimated recharge rates derived from multiple techniques (including the model) for the CLA - see also Currell and Ndehedehe, (2022) - indicates that there are considerable margins of uncertainty in these parameters, which cannot be resolved through model calibration alone.

Satellite-based estimates of recharge

There are further lines of evidence, which can contribute to an understanding of recharge rates, mechanisms and relationship to climatic variables that have not been incorporated into the SREBA studies, e.g., analysis of satellite-based gravity and related remote sensing data.

Data from the Gravity Recovery and Climate Experiment (GRACE), which was launched in 2002 have helped to improve our understanding of the impacts of climate change and human water extraction on groundwater hydrology globally. Be it local or global, the use of GRACE in assessing groundwater status and water budget is well known (e.g., Rodell et al., 2018) and recently, its feasibility in recharge estimation, and identifying areas where groundwater drawdown exceeds recharge, has been established (Rockstrom et al, 2023; Stewart-Koster et al., 2023). The use of GRACE data to estimate annual recharge for the extended SREBA water study area, following the methodology outlined in Stewart-Koster et al., (2023), confirms that there is strong variability between years (Figure 5). Extreme wet and dry years result in considerable differences between high and low recharge values, consistent with a highly episodic recharge regime. The northern section of the SREBA area receives the highest annual recharge, coinciding with the strong annual rainfall. While mean annual recharge in years with above-average rainfall may exceed 300 mm, recharge is restricted in years with below average rainfall (e.g., 2013, 2016), ranging from 50-70 mm/yr (Fig. 5).

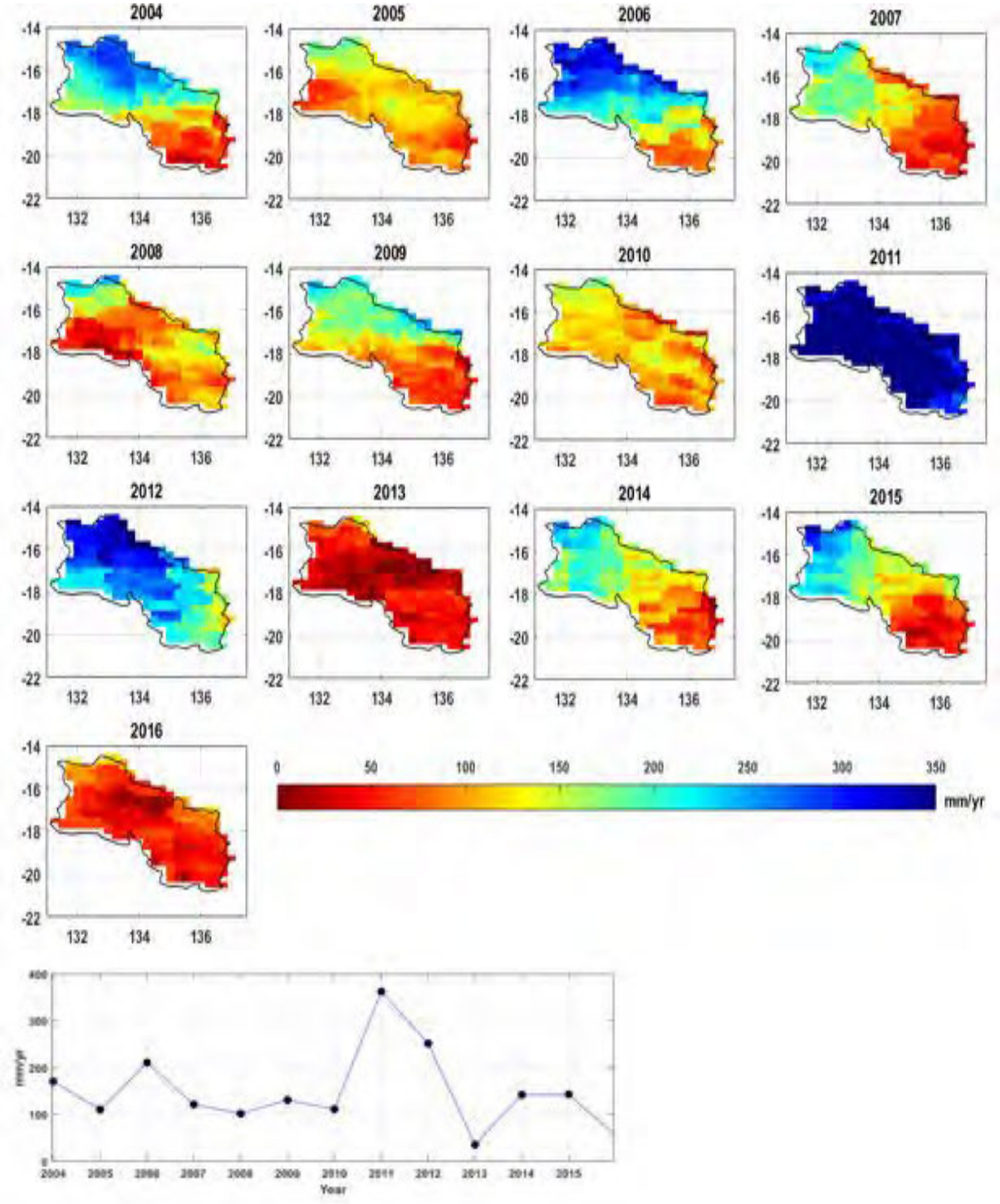


Figure 5 - Changes in spatial distribution of annual recharge between 2004 and 2016 over the CLA (bottom panel shows aerial averaged temporal variation), estimated from satellite gravity data (Ndehedehe, this study).

Trends in annual recharge assessed for the 2004-2016 period using GRACE show gradual declines around the Beetaloo sub-basin and Beetaloo eastern extension (Figure 5), illustrating impacts of climate variability on recharge. The approach recognises the complex interactions associated with groundwater recharge, especially how extremes in climate can restrict recharge a surface water availability. Pixel-based recharge values were estimated using annually aggregated groundwater values

processed from the GRACE data, and trends subsequently estimated for the 2004-2016 period (Figures 5 & 6).

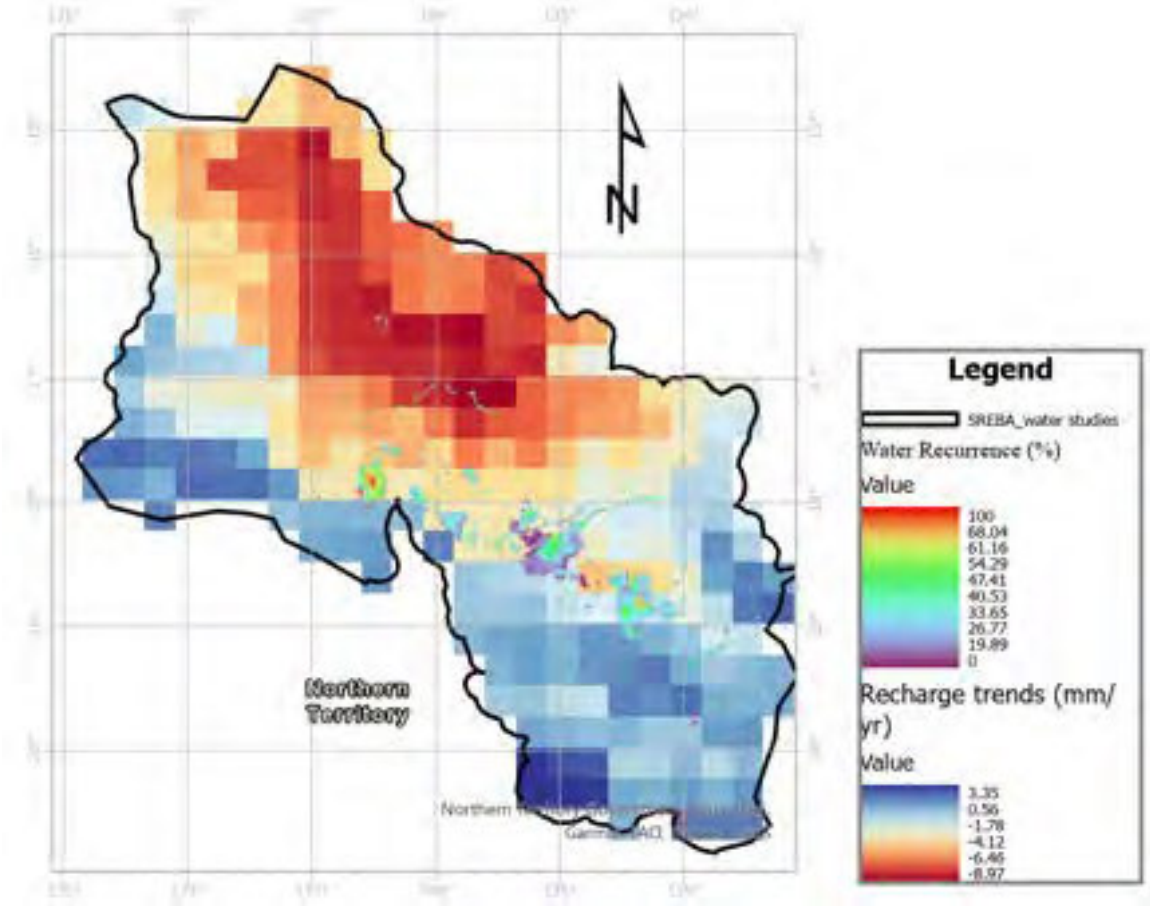


Figure 6 - Trends in annual recharge rate (2004 and 2016) estimated from satellite gravity data, and water recurrence based on historical Landsat data (Ndehedehe, this study). The background raster map is recharge rate trend, while the overlay/inset is water recurrence.

Due to the high connectivity between the CLA aquifers throughout the SREBA area (see previous section of this review) there may be a considerable risk of alteration of natural patterns and variability of groundwater recharge, as well as groundwater discharge, if significant increases in water extraction occur (Currell and Ndehedehe, 2022). As discussed in Alley et al., (1999) and other studies examining methodologies for determining a Sustainable Yield, extraction of groundwater does not just change volumes of water in storage. It also results in changes to rates and locations of discharge of groundwater to the surface (typically reducing these in the long-term) as well as recharge rates, and patterns of ground-surface water interaction. For example, excess available surface water (shown as water that has a relatively low recurrence – Fig 6) may be drawn into the affected aquifer(s) as a new recharge source, to replace water being extracted. Understanding these changes and their environmental, social, and economic implications, is critical for effective sustainable yield determination.

Globally, there is considerable interconnection between groundwater and surface water systems, as much streamflow benefits from groundwater baseflow (Berghuijs et al., 2023). In the event of large-scale increases in groundwater extraction in the SREBA

area, impacts on groundwater-surface water interactions that further limit groundwater flows to streams and springs would be likely to occur. This is discussed in detail in Currell and Ndehedehe (2022), which examined the issue of appropriate sustainable yield determination for the CLA. Importantly, the recharge and discharge rates and mechanisms for the other aquifer units below the CLA within the SREBA area – such as the Neoproterozoic Sandstones, remain poorly understood, along with their interconnections with the CLA and surface environment (see previous section). This adds to uncertainty regarding appropriate sustainable yield determination in the SREBA aquifer system.

Excess water or 'Available Water'

The SREBA studies provide some new insights into groundwater discharge processes, using remotely sensed data. 'Excess water' or net precipitation was investigated at identified springs, by quantifying the difference between actual evapotranspiration and precipitation during the 2000-2022 period (Gautam et al., 2022). While actual evapotranspiration represents outgoing fluxes or water loss from a catchment, 'excess water' can serve as an indicator of water availability and help assess potential future changes to water budgets. The significant change in water balance in the spring systems reported by Gautam et al., (2022) confirms the vulnerability of the CLA to drought impacts. Prolonged below-normal precipitation increases evaporative demand, resulting in some vegetation communities (which are not groundwater-dependent) being reliant on groundwater. This can happen when excess water declines due to increases in actual evapotranspiration under limited rainfall. Since 2011, there is a significant decline in cumulative 'excess water' for two of the spring systems (Flora and Mataranka) reported in Gautam et al., (2022). This was attributed to evaporative losses from surface water at Flora River and increased water uptake by vegetation at Mataranka. Further,

> "..there is also sporadic evidence of groundwater use at the two southern sites [Top Springs and Hot Springs Valley], such as during the 2018–2020 period when P-AET (excess water) shifted to negative values".

There remain knowledge gaps regarding water availability and/or changes to 'excess water' within other parts of the SREBA, including the dynamics of interactions between ground and surface water bodies shown on Figure 6 above (which is based on satellite gravity data-trends in recharge over time and Landsat data on permanence of surface water bodies), in addition to the spring complexes mentioned above. The importance of knowledge around surface-groundwater hydrological fluxes, among other aspects of the water balance, is acknowledged in Gautam et al., (2022):

> "Further research and modelling into closing the water balance would provide a more in-depth view of the water condition and help understand the role of groundwater in sustaining riparian ecosystems across the region".

Sustainable Yields

The question of what constitutes a Sustainable Yield in different aquifers and regions within the SREBA is a critical aspect of addressing the Pepper Inquiry

recommendations / SREBA Framework objectives. This topic is discussed extensively in our previous report focussing on the Cambrian Limestone Aquifer (Currell and Ndehedehe, 2022). To briefly summarise key findings:

- Determining sustainable yields should focus on determining where reductions in groundwater discharge will occur in response to groundwater extraction at different rates (and any additional recharge drawn into the aquifer from the surface), and how important these waters are from environmental, economic, and socio-cultural perspectives (Alley et al., 1999). Direct impacts of storage depletion - e.g., drawdown to the point that GDEs, including terrestrial vegetation, can no longer access groundwater – should also be considered (alongside changes to discharge and recharge).

- In the arid, southern regions of the CLA, where recharge is highly episodic, the calculation of an estimated sustainable yield based on long-term average recharge rates is problematic, as there may be extended periods (i.e., decades) in which recharge is well below the mean. In turn, extraction at a sustainable yield that is derived based on an annual long-term average recharge, would result in significant reductions in groundwater levels and fluxes, potentially for many years (or decades) consecutively. The recurrence interval for major recharge events in episodically-driven systems (such as the southern, arid zones of the SREBA area) may be very long – the last major episodic event appears to have occurred associated with extreme rainfall in 1974, and this remains poorly quantified / understood due to lack of monitoring at the time.

Moreover, there appears to be limited understanding of the water balance and connections between ground and surface water associated with other aquifer units (apart from the CLA) e.g., Lower Cambrian Volcanics and Neoproterozoic sandstone aquifers. As discussed in other sections of this report, the groundwater hydrology, aquifer parameters and connectivity between these aquifers and their overlying / underlying hydrogeological units (including the CLA) are poorly understood. This means that a comprehensive analysis of sustainable yields for these aquifers, and the potential impacts on other aquifers (through connectivity) is not yet possible.

A summary of key findings regarding this SREBA Framework objective is:

- Long-term average diffuse groundwater recharge rates for the CLA are relatively well-constrained in the SREBA area. However, multiple recharge estimation techniques provide quite different overall rate estimates (indicating ongoing uncertainty) and the coverage of data and degree of confidence in the estimates is better in certain areas than others (e.g., data are limited in the Wiso basin). While some additional analysis of recharge through other mechanisms (e.g. sinkhole recharge) has been included in the SREBA reporting, it does not appear that the SREBA studies have generated a significant amount of new data to inform a more comprehensive quantification of recharge rates and their variability / uncertainty.

- There is a lack of available data to inform an understanding of the importance, rates and mechanism(s) of rare, episodic groundwater recharge events within the

semi-arid/arid parts of the SREBA, to help inform assessments of the long-term regional water balance. Localised recharge rates and mechanisms (e.g., their relative importance of diffuse vs. preferential/focussed recharge) remain generally poorly understood. This must be carefully considered and addressed to develop robust estimates of sustainable extraction rates.

- Reliance on numerical modelling to estimate recharge rates – which is a primary technique in updated regional water resources assessments - must consider the high possibility of model non-uniqueness (due to the uncertainty of multiple different model input parameters). This means that model calibration may not effectively constrain the rates of recharge within robust and precise ranges.

- Additional analysis of remote sensing data can help to constrain recharge and its dependence on climatic variables, as well as understanding the importance of groundwater in sustaining surface water and vegetation through different climatic periods. Preliminary data analysed in this study and SREBA studies, indicate that both recharge rates and the permanence of surface water (connected to groundwater) vary considerably with yearly climate, undergoing periods when recharge rates are low, and vegetation becomes strongly dependent on groundwater. There remain considerable unknowns with respect to climate-groundwater-surface water interactions, however. These interactions must be understood (together with recharge), to develop robust sustainable yield estimates.

- Estimation of sustainable groundwater extraction rates requires considerable further data and analysis. This should encompass a comprehensive understanding of groundwater discharge rates and mechanisms (which sustain surface water, vegetation and GDEs) and potential changes to these under various extraction scenarios. Current sustainable yield estimation appears to have been largely conducted using water balance estimates derived from groundwater numerical modelling; however, the full methodology and assumptions are not available to be reviewed in detail (since reporting on the DR2 model by Knapton, 2020).

- Data gaps relating to the hydrogeological parameters, water balance and inter-aquifer connectivity for the aquifer units below the CLA (e.g. Neoproterozoic sandstones) mean that sustainable extraction rates from these units, and potential impacts of extraction from these on other aquifers (including the CLA) cannot be determined.

Objective 4: "Develop suitably calibrated groundwater-surface water flow models to quantify the connectivity between groundwater and surface water systems to predict the likely impacts of hydrological perturbation as the result of any potential onshore shale gas development and production."

Water resource assessments, based on coupled numerical ground-surface water modelling, have been published for the major regions/sub basins of the SREBA area - Wiso Basin, Georgina Basin and Flora water management area. The modelling used to underpin these water resource assessments is documented (to a degree) in Knapton (2020) – i.e., the DR2 model. According to the Georgina Basin water resource assessment report, this model has not been revised/updated significantly since 2020:

> "The most recent upgrade of the model occurred in 2020, and included updated aquifer geometry and conceptualisation, and an additional 10 years of field monitoring and climate data."

As such, any more recent drilling data, hydraulic testing of aquifers, and hydrograph information (for transient calibration) that was collected since 2020 (e.g., as part of the SREBA studies) would not be included in the modelling.

Currell and Ndehedehe (2022) examined the modelling documented in Knapton (2020) in the context of assessing whether there was sufficient basis to enable quantification of sustainable extraction rates from the CLA aquifer system. Currell and Ndehedehe (2022) noted some important knowledge gaps in this regard. They also recommended against the use of fractions of estimated aquifer storage volume or estimated average recharge rates in the calculation of sustainable yields as these remain uncertain, and do not capture all aspects of the impacts of extraction. Determination of sustainable yields additionally requires comprehensive analysis of the full aquifer system's regional and sub-regional water balances (including robust estimates of inter aquifer leakage rates), rates and locations of groundwater discharge to surface water and other groundwater dependent ecosystems, and the likely relative components of storage depletion vs. capture of groundwater discharge under different water extraction scenarios. These conclusions remain unchanged in light of the SREBA water studies.

A further detailed review of the suitability of the DR2 model for addressing this SREBA Objective is not included in this review, as:

a) There is not (to our knowledge) further detailed documentation of upgrades to the DR2 model's parameterisation or calibration beyond what is outlined in Knapton (2020), or comprehensive documentation of the modelling of new water extraction scenarios simulated by the model;

b) The authors are not expert numerical groundwater modellers, and a review of the modelling (if the relevant material were available) would best be conducted by a dedicated groundwater modelling professional or organisation with such expertise. The modelling review should have access to full details regarding modelling assumptions, parameterisation, calibration, and uncertainty analysis.

Objective 5: "Establish a baseline for water quality, including measuring vertical profiles of water quality parameters through potentially affected aquifers and surface waters, noting that this will need to be done at a number of locations across a region to inform the lateral variations in quality. In semi-arid and arid regions, particular attention should be paid to the water quality of perennial to near-perennial water bodies that are likely to provide dry season refugia for aquatic biota and drinking water sources for wildlife[4]"

Groundwater quality data compiled and collected during the SREBA water studies are summarised in Shand et al., (2022) and ELA (2022). There is a substantial amount of groundwater hydrochemical data available from bores in the SREBA area (see Figure 7). However, similar to groundwater level baseline data, some aquifer units have much greater availability/coverage of water quality data than others.

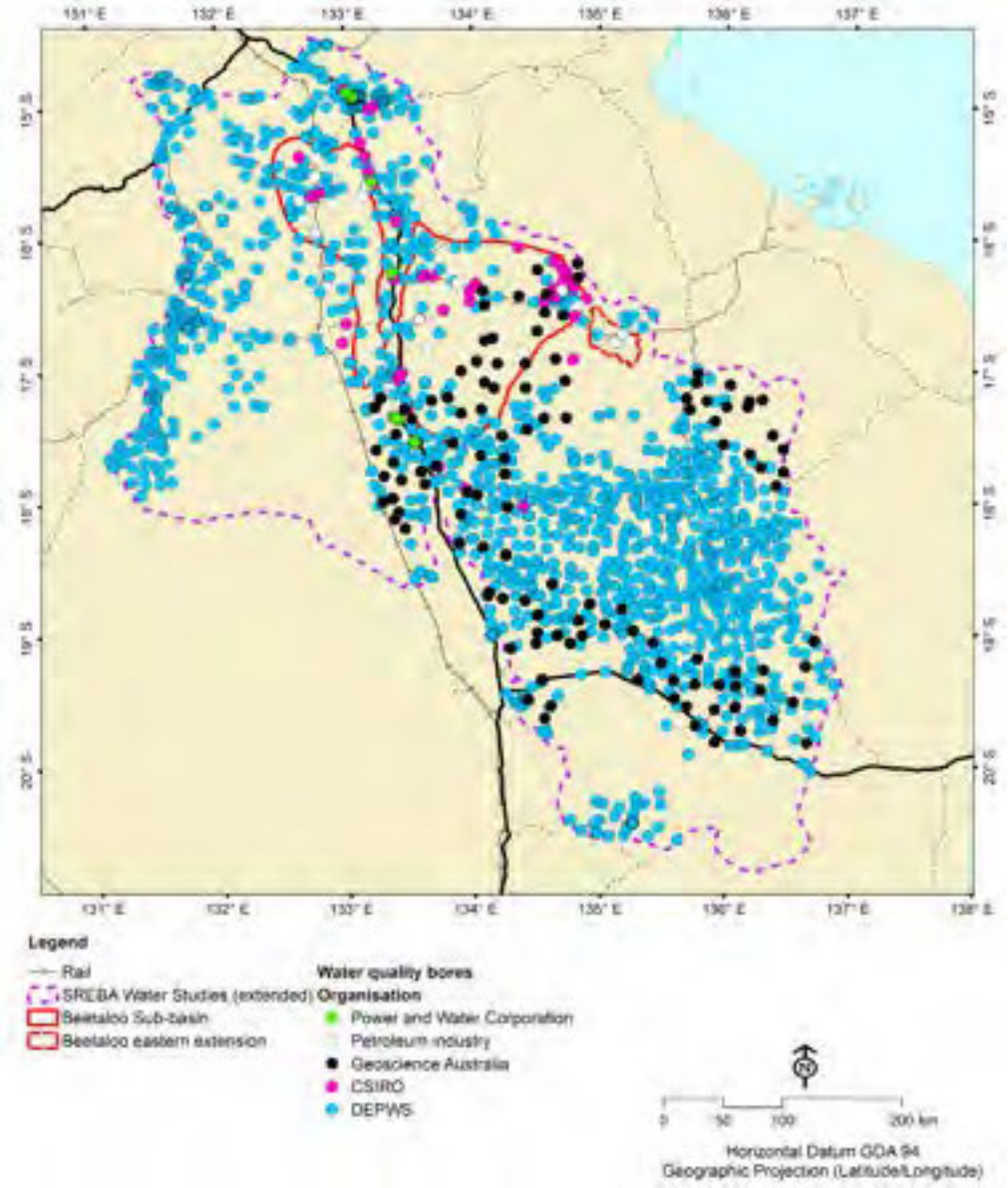


Figure 7 – Locations of bores where at least one groundwater quality measurement is available (ELA, 2022).

[4] Note: The analysis here is confined to the topic of groundwater quality baseline data, as the reviewers do not have extensive expertise in surface water quality requirements for aquatic biota.

What should a groundwater quality baseline in areas of unconventional gas exploration include?

There is an extensive global literature on the issue of potential impacts of shale and other unconventional gas development on groundwater quality, and requirements for comprehensive baseline data in such regions (Vidic et al., 2013; Jackson et al., 2013a; Vengosh et al., 2014; Humez et al., 2016; US EPA, 2016). Analysis of relevant studies from other contexts (particularly the US, where a shale gas industry is established) was considered in the Pepper Inquiry and formed part of the basis for the recommendation(s) with respect to baseline groundwater quality. Briefly, a comprehensive baseline dataset should include:

- Sufficient coverage of water quality samples throughout the aquifers of interest (including different depths) and sufficient time-series data to allow for a statistically robust analysis of the range and variability of groundwater quality characteristics for these aquifers. This is required to assess any future changes due to gas extraction and associated activities and clearly identify the significance of changes in water quality parameters;

- Extensive data for water quality characteristics / contaminants that are likely to be associated with shale gas. Dissolved methane concentrations are critical in the context of fugitive/stray gas risk (Jackson et al., 2013b), and the isotopic composition of methane and other hydrocarbon gases should be documented so that sources of any potential fugitive gas identified in water supply bores can be fingerprinted (Jackson et al., 2013b; Humez et al., 2016). Other common trace elements that are associated with shale gas brines and present in fracking flowback waters also need detailed baseline characterisation in shallow aquifers and surface waters, in particular elements like barium, strontium and radium, which are often enriched in shale brines (Warner et al 2013). Microbial communities in the aquifer system may also be substantially impacted by oil and gas development, and may serve as important indicators of processes causing water quality changes, including stray gas contamination (e.g. Van Stempvoort et al., 2005). Such indicators should be included in baseline water quality datasets along with hydrochemical and isotopic parameters.

- Field groundwater physico-chemical parameters – redox potential (Eh/ORP), pH, DO and EC are a very important aspect of baseline groundwater quality, as unconventional gas development impacts (such as fugitive gas migration or inter-aquifer leakage) may trigger changes in these variables, such as through catalysing redox reactions in the aquifer(s) in response to changes in dissolved oxygen and redox potential. These indicators can be important early warning indicators of an impact on groundwater quality.

- These data and their analysis should also allow for baseline understanding of the key processes that impact groundwater quality – e.g., soil zone reactions and evapotranspiration during groundwater recharge, water-rock interaction within the different aquifer units, inter-aquifer mixing (either natural or induced),

redox and other geo-microbiological processes impacting on contaminant concentrations. Thus, data must not simply be collected and reported as concentration levels and ranges as an end in itself, but must also be continuously analysed and interpreted with respect to hydrogeochemical processes. Such understanding is required so that any future change in the dominant processes affecting groundwater quality can be effectively determined (Jackson et al., 2013a & b).

The extent to which the current data and analysis of these addresses these objectives are examined further below.

Extent of coverage of baseline groundwater quality data in the SREBA area

ELA (2022) summarised the findings of the review of groundwater quality baseline data commissioned for the SREBA by the National Centre for Groundwater Research and Training (Shand et al, 2022), noting that the available data were 'useful for providing a broad-scale overview of water quality trends across the primary HSU of concern (i.e., the CLA).'

However, regarding the Neoproterozoic sandstone aquifer(s), Antrim Plateau Volcanics and the deeper Beetaloo basin hydrostratigraphic units, the baseline water quality data are much more limited (Shand et al., 2022). There are 4744 total groundwater quality records available from within the SREBA area - the majority from the CLA (> 2800). Water quality baseline coverage is limited in other deeper aquifer units below the CLA (below 150 m depth) with Neoproterozoic and Mesoproterozoic rocks having approximately 250 samples – among which only five are from the Bukalara Sandstone - and the Antrim Plateau Volcanics approximately 140 samples (see Table 2 of Shand et al 2022). Shand et al. (2022) noted:

> "There are very few samples from the formations underlying the CLA i.e. the Bukalara Sandstone (5 samples or 0.1% of the data) and the Cox Formation no samples."

The gap in available water quality/hydrochemical data for the units below the CLA is a significant issue, as the future identification of the cause(s) for changes in water quality parameters in aquifers that are utilised more extensively (e.g., the CLA) requires suitable characterisation of end-member concentrations of water quality components in other potentially connected hydrostratigraphic units. These units may influence groundwater quality through (for example) inter-aquifer leakage caused by water or gas extraction (Ayotte et al., 2011).

As noted in Tickell (2022) and Shand et al., (2022), there has been (as yet) limited analysis of the available hydrochemical data to understand the major processes and controls on water quality within the different aquifers (noting that Shand et al 2022 document some initial steps and recommendations in this regard).

> "To date, no regional study has been carried out on variations in groundwater quality. Various parameters have been mapped but little interpretation of the data has been made. The water quality dataset is extensive and offers an opportunity to obtain more information about processes such as recharge and

rock-water interaction. Studies of the level as those done by de Caritat et al. (2019) and Brodie et al. (2021) are considered applicable to the CLA. A certain amount of additional sampling would be necessary to fill in data gaps." (Tickell, 2022).

Additional bores drilled for the SREBA to inform water quality analysis

ELA (2022) contains details of the new groundwater bore drilling and quality sampling conducted for the SREBA. In total, 23 new bores were drilled (See Figure 2), among which 20 were sampled (in two events) specifically for groundwater quality baseline data. Coverage of monitoring bores, encompassing these new sites, across the SREBA area is relatively dense in regions of existing groundwater extraction and historic government monitoring programs (e.g., near Mataranka); but remains sparse in other areas, such as between and Larrimah, Daly Waters and Elliot, and the central Wiso and Georgina Basins (Figure 2). These are areas that overlie the Beetaloo sub-basin rocks and thus may be targets for unconventional gas and groundwater extraction.

The rest of the baseline groundwater quality data reviewed in ELA (2022) and Shand et al., (2022) were collected associated with other projects - e.g., conducted by CSIRO/GISERA and Geoscience Australia, or previous/ongoing NTG monitoring programs. As with the water level monitoring data, there is a strong bias in most studies towards sampling within the CLA – the primary water supply aquifer – with smaller numbers of samples collected from deeper units.

Vertical (and lateral) profiling of groundwater quality and geochemistry

A key aspect of Objective 5 of the SREBA Water Studies (see above) is the characterisation of hydrochemistry and water quality along vertical profiles – i.e., at nested monitoring bores tapping the different aquifer units at different depths. As discussed under the review of Objectives 1 and 2 above, nested groundwater monitoring sites within the SREBA area are rare (e.g., confined to 5 sites with paired bores tapping the upper/lower CLA, and two sites where the CLA and Bukalara Sandstone are both monitored). Hence the objective of vertical groundwater quality profiling remains largely un-addressed.

Ensuring this data/knowledge gap is resolved – along with better understanding of vertical inter-aquifer connectivity between Proterozoic and Cambrian units (see above) is vital to the protection of shallow groundwater resources in areas of potential gas development. End member concentrations and isotopic compositions of key potential contaminants associated with shale gas development (such as methane, boron, and lithium) are required both from water supply aquifers, and units targeted for gas development. This is needed both to detect future impacts, and accurately determine their cause and mechanism (Jackson et al., 2013a; Warner et al., 2014).

Baseline data for key hydrochemical parameters in the context of potential gas development

Shand et al (2022) examined the available data for different water quality/ hydrochemical parameters within the available baseline datasets, within the major

hydrostratigraphic units. A brief summary of the findings (with particular focus on constituents highly relevant in areas of unconventional gas) is given below:

Pysico-chemical parameters

Shand et al., note that data coverage for EC, pH, redox and dissolved oxygen is poor – with fewer than 10% of water quality analyses reporting these parameters. This is important as these parameters are needed if any geochemical modelling is to be carried out, and they can be highly sensitive indicators of potential groundwater impacts associated with hydrocarbon extraction (Van Stempvoort et al., 2005).

Major ions and nutrients

Most of the water quality analyses contained in the baseline datasets include data for major ions, minor ions and nutrients (although generally only nitrate data are available, with limited ammonia and nitrite).

Microbiological components of groundwater

A relatively small subset of bores within the SREBA groundwater quality database (reviewed by Shand et al (2022)) have data on the makeup and prevalence of bacterial communities in the groundwater:

> "Different bacterial analyses (Plate Counts and Coliforms/Streptococci) are available for between 0.7 and 13% of the data. The data were often 'ND', which we assume is not detected.

Van Stempvoort et al., (2005) identified Sulfate Reducing Bacteria (SRB) as a key monitoring parameter in identifying contamination associated with oil and gas activity in Alberta, Canada. It is unclear whether analysis of these bacterial communities has been conducted in the aquifers within the SREBA area.

Organic compounds and gases

A total of 46 organic components are present in the dataset. The main custodians for the data are CSIRO, Geoscience Australia and gas companies. They are typically in the range of 4-8% of analysed samples. Methane concentrations in groundwater have been reported for bores in certain regions of the SREBA area (discussed below in conjunction with methane isotopes).

Minor/Trace elements & radionuclides

Trace element analysis was identified in 0.2 to 18% of samples, while approximately 4% of samples had analysis for gross alpha and beta activity (mainly CSIRO and onshore gas company data). It is assumed that among the trace elements analysed, there would be reasonable coverage of parameters that are important in the context of unconventional gas – e.g. barium, strontium, boron, radium, although a detailed examination of the datasets for these parameters has not been conducted here.

Methane concentrations and isotopes

Methane concentrations in groundwater have been recorded in 216 instances (Table 4 of Shand et al, 2022); among which all but 15 samples are in the CLA. Methane data

from deeper units appear to be highly limited. This is an important knowledge gap given the need to understand the risk of fugitive gas migration in regions of potential unconventional gas activity (Jackson et al., 2013a & b).

It does not appear that any extensive sampling of groundwater for environmental isotopes, to support baseline groundwater quality assessments, was carried out through the SREBA water studies (noting that some isotope data were collected for assessment of flow paths and timescales of flow to the Flora River, by Irvine and Duvert, 2022). This is an important aspect of baseline groundwater quality programs in areas of potential unconventional gas development (e.g., Jackson et al., 2013a & 2013b), as it is required to distinguish different potential sources of methane in groundwater – e.g., thermogenic gas associated with shale gas deposits, vs. gas produced in shallow aquifer via microbial degradation of organic matter.

Data were collected on methane concentrations and isotopic compositions in bores within the SREBA area for a GISERA project (Wilkes et al., 2019) and for the Northern Australia Hydrogeochemical Survey (NAHS) (Schroder et al 2021), which partly overlapped with the SREBA boundary. In combination, these two studies analysed approximately 100 samples for methane concentrations in groundwater (spread across the Beetaloo sub-basin, Tennant Creek, McArthur River and Nicholson South). This review identified 7 samples where isotopes of methane were successfully analysed among the 100 samples (which are a sub-set of the 216 samples identified in Shand et al., 2022).

This is very limited coverage considering the size of the SREBA area and the number of aquifer units potentially containing methane - which could migrate between aquifers as a result of shale gas development. For comparison, the Victorian government's Water Science Studies in the Gippsland and Otway basins, conducted during the Parliamentary inquiry into Unconventional gas (Victorian Government, 2015a & b; Currell et al 2017) sampled a total of 60 bores for methane concentrations (along with major ions, nutrients and a range of hydrocarbons), among which 38 bores were analysed for methane isotopes, including multiple aquifers and depths. Unconventional gas development was at that time only considered a potential scenario (which did not ultimately progress), and the industry and its approvals were at a much less advanced stage than currently in the NT. Characterisation of methane concentrations and isotopic compositions in the SREBA area thus remains a significant knowledge gap.

Summary

A considerable quantity of groundwater quality baseline data have been compiled through the SREBA, including major ion, trace element, and to some extent hydrocarbon and microbial characteristics. A set of additional bores drilled for the SREBA provides some level of increased coverage of water quality data; the data coverage is considerably higher within the CLA compared to other geological units within the sequence from the Beetaloo sub-basin to the surface.

Key knowledge and data gaps in the groundwater quality baseline for the SREBA area to address Objective 5 include:

- A general lack of groundwater quality data for aquifers and hydrostratigraphic units below the Cambrian Limestone Aquifer – e.g., very few analyses from the Bukalara Sandstone, units within the Beetaloo sub-basin and Antrim Plateau Volcanics;

- A lack of detailed characterisation of the major hydrogeochemical processes that control groundwater quality in different aquifers / units within the SREBA area.

- A lack of vertical profiles of groundwater quality/geochemistry with depth, e.g. from the CLA down to the Proterozoic units (and encompassing horizontal transects that capture variability in these vertical profiles associated with geological and other controls), as per SREBA Framework Objective 5

- Limited environmental isotope/tracer data, microbiological analyses and trace/minor water quality components that are important potential indicators of water quality impacts associated with unconventional gas development;

- Characterisation of key isotopic end-member compositions of different waters within the SREBA aquifer system, to enable future analysis of potential causes of any changes in groundwater quality (e.g. due to inter-aquifer mixing induced by greater rates of groundwater extraction, fugitive gas migration in response to gas development, or leakages/surface spills of fracking fluids).

Conclusion

The SREBA water studies were commissioned in response to recommendations of the Scientific Inquiry into Hydraulic Fracturing in the NT and have since collected and compiled a substantial amount of groundwater-related data, towards addressing the SREBA Framework objectives and Pepper Inquiry recommendations. This review has found that, while some of the SREBA water objectives have been largely addressed (or there has been substantial progress towards them), there are still major knowledge and data gaps on topics that are central SREBA Framework objectives. These knowledge and data gaps are summarised at the end of each section of this report and in the Executive Summary.

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The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Groundwater Dependent Values

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Executive Summary

This report presents a concise review of the hydrogeology of the Cambrian Limestone Aquifer (CLA) in the Northern Territory (NT), and the ecological and cultural values sustained by its groundwater. It examines risks to these values associated with different approaches to the assessment of groundwater license applications in the CLA, including using the Top End and Arid Zone contingent rules, which apply in areas without a Water Allocation Plan (WAP), and other approaches proposed in draft WAPs (e.g., Georgina-Wiso). The report concludes with recommendations about appropriate methods and safeguards to protect the CLA's groundwater and the values it sustains, in line with recommendations of the Pepper Inquiry. The major focus is the areas of the CLA where WAPs are in progress – Flora Tindall, Mataranka and Georgina Wiso.

The Cambrian Limestone Aquifer (CLA) ranges from <50 m to over 400 m thick, covering much of the NT. The aquifer comprises inter-layered limestone and mudstone. Groundwater occurs largely within secondary porosity (fractures and karst features). The CLA is overlain by younger Cretaceous rocks; where these are absent, recharge to the aquifer and/or discharge to surface water occur. Below the CLA sits the Beetaloo sub-basin, a sequence of Proterozoic sedimentary rocks that host saline groundwater, oil and gas. The CLA occurs in three basins - Daly, Wiso, and Georgina. There is cross-basin connectivity between the equivalent limestone units within these.

Local recharge within each CLA basin appears to exceed rates of throughflow between adjacent basins, based on environmental tracer data and modelling. Throughflow remains poorly quantified but appears nonetheless to be a significant part of the water balance. There are also indications of vertical inter-aquifer connectivity - e.g., deep groundwater below the CLA contributing to spring flows at Mataranka Thermal Pools (in addition to CLA groundwater). Recharge to the CLA occurs by diffuse percolation of rainfall in areas where Cretaceous cover is thin or absent, at rates generally between <1 and 30 mm/yr, increasing from south to north. There is also evidence of recharge at higher rates (>100 mm/yr), associated with karst features (e.g., sinkholes). Discharge of groundwater to the surface appears to be limited to small but environmentally and culturally significant areas, where it sustains vitally important groundwater dependent ecosystems (GDEs).

Groundwater from the Tindall Limestone flows to the surface via springs, wetlands, and the channels of the Roper and Flora rivers and associated tributaries. These groundwater flows support significant vegetation communities and aquatic ecosystems within spring pools, groundwater-dependent sections of streams, and downstream waterbodies. Fauna drink from groundwater-fed pools and terrestrial vegetation utilises groundwater where the CLA water table is shallow. GDEs are also found within the aquifer matrix, i.e., stygofauna, including crustaceans, within caves and cavities in the rock. These groundwater dependent sites, waters, fauna, and vegetation and are of great cultural significance to Aboriginal peoples of the region. Aboriginal peoples' oral accounts highlight the interconnectedness of the region's groundwater, surface water and landscape, and both human and non-human living communities, as well as ancestral beings.

WAPs are not currently in place for the region encompassing the CLA and Beetaloo sub-basin, but are expected to be finalized in 2022-23, in accordance with recommendations from the Pepper Inquiry. A draft WAP for the Georgina-Wiso region is currently open for public review. Current rules for groundwater licensing where WAPs are not finalized use the Top End and Arid Zone contingent rules, to set caps on groundwater extraction rates for consumptive use in a given area. The Top End rules allow for allocation of groundwater licenses up to a fraction (20%) of estimated recharge. This approach is broadly in line with other groundwater management jurisdictions in Australia and worldwide, which calculate a Sustainable Yield as a fraction of recharge and/or discharge with the intention of balancing extraction with a need to maintain long-term groundwater access and limit impacts on GDEs. It should be noted however, that this method and/or the value of 20% may not always achieve these aims, due to complicated re-distribution of water balances in response to groundwater extraction. It remains unclear whether extracting 20% of recharge in aquifers

currently classified as Top End (such as the Tindall Limestone) would have unacceptable consequences for GDEs. Preliminary analysis indicates significantly reduced flows to the Roper River could result, which would be particularly noticeable during dry periods.

The Arid Zone rules, which apply to the south of a line delineating northward and southward flowing surface water catchments of the NT, contain two clauses relevant to groundwater. The first states that licensed extractions should have no detrimental impacts on GDEs; the second allows for depletion of 80% of total pre-development groundwater storage, over a 100-year timeframe. These two aspects of the rules are contradictory. It is not possible for the first aim to be achieved if the second part is permitted. In accordance with the conclusions of the Pepper Inquiry, using storage volumes to calculate sustainable yields is not in line with ecologically sustainable development and risks harm to groundwater dependent values. Aquifers should not be described in terms of total storage when considering sustainable yields or 'safe' extraction rates. It is the water flows to and from the aquifer sustaining other aspects of the water cycle and dependent values (e.g., flows to springs, rivers and vegetation) that are most important in assessing sustainable yield. These flows are normally very small in comparison to the total water in an aquifer's storage; hence, extracting even small proportions of overall storage can have significant water cycle consequences (e.g., reduced baseflows and/or loss of groundwater dependent ecosystems).

The Arid Zone contingent allocation rules appear to be one of the only cases in Australia where a storage-based approach is applied to the determination of a 'sustainable' yield. If this approach were to be adopted in WAPs covering the CLA and Beetaloo sub-basin and/or remains in use more generally, it would allow for unsustainable development of groundwater, with serious potential consequences for groundwater dependent ecosystems, cultural values and water users. In the Daly Basin/Tindall Limestone section of the CLA, where the Mataranka springs and Roper River occur, extraction at rates that cause long-term storage depletion would endanger these and other important GDEs, by reducing spring discharge, river baseflow and water table levels.

The current draft WAP for the Georgina Wiso region proposes an estimated sustainable yield (yearly extraction cap) of 262.6 GL/year, estimated to be 40% of long-term averaged recharge. It is unclear how or why the value of 40% of recharge was determined to represent a sustainable level of extraction. In the Georgina and Wiso Basins, knowledge of the water balance, hydrogeology and groundwater dependent ecosystems are currently not sufficient to fully understand the effects of such extraction. The recharge estimate used to derive the ESY is model-derived and has considerable uncertainty. It is nearly double the value derived from earlier runs of the same model, and higher than some field-based estimates, meaning the ESY may constitute a larger fraction of recharge than assumed. The current data also indicate that recharge is considerably lower than the long-term average in most years (and may be negligible under the typical climate), except for rare events where rainfall (and recharge) far exceeds the rolling long-term average. Such periods have likely occurred only three or four times over the past century. The vast majority of estimated recharge to the Georgina and Wiso basins is associated with a single event in 1974. The recurrence interval for such recharge events, and details of their mechanism remain unknown. Therefore, under the proposed ESY, in most years, significant aquifer overdraft (extraction far exceeding recharge) would be permitted. Such overdraft may occur for many consecutive years (or decades), before the next episodic recharge event occurs.

Drawdown associated with consecutive years (or decades) of aquifer overdraft in the Georgina and Wiso basins would endanger stygofauna communities and reduce cross-basin discharge fluxes within the CLA, e.g., to the Tindall Limestone aquifer (upon which key GDEs noted above depend). Currently, groundwater discharge mechanism(s) from these two basins is poorly understood. There may be additional groundwater dependent ecosystems within or close to the edge of the plan area sustained by CLA groundwater (such as springs in the western Wiso Basin, or un-mapped deep-rooted vegetation communities). These GDEs may suffer reduced access to groundwater for extended periods between recharge events due to extraction at the proposed ESY, threatening

their survival. Water quality risks, such as migration of saline water into fresher parts of the aquifer, and potential aquifer integrity issues associated with concentrated extraction in particular regions have also received limited or no attention in the draft WAP. Better characterization of GDEs, recharge and discharge mechanisms and rates, and more comprehensive assessment of these risks are urgently required before appropriate management rules can be adopted to ensure the Georgina-Wiso WAP does not lock in negative impacts on environmental and cultural values.

Sustainable management of groundwater extraction throughout the CLA should adopt a management approach in line with contemporary best practice, that sets:

1) **Volumetric extraction rate limits** which in the long-term ensure:
   A) groundwater flows and levels do not decline in such a way as to compromise the health of the groundwater dependent ecosystems, water quality and aquifer integrity. This requires careful analysis of recharge and discharge flux rates, environmental dependencies on these flows, and the extent of 'capture' and drawdown caused by pumping at different rates.
   B) the renewability of groundwater resources, ensuring prevention of long-term storage depletion and/or detrimental capture of surface flows - recognising the value of the Roper River, Mataranka springs and other GDEs supported by the CLA.

2) **Clearly defined and well monitored groundwater level thresholds**, determined to be the elevations required to sustain environmental and cultural values of groundwater dependent sites and ecosystems – including through the maintenance of throughflows between the CLA basins. When these levels are approached or crossed, reductions in groundwater pumping should be triggered, in line with level-based management approaches adopted in other parts of Australia and internationally. Trigger levels must be set appropriate distances from environmental assets seeking to be protected to account for time-lags.

Setting both a cap on total extractions in declared management zones, along with a series of water level thresholds and buffer zones to protect GDEs, would be in line with international best practices, if implemented alongside a robust monitoring program. Further, any rules developed to allow trading of groundwater should restrict the trade of extraction permits into areas close to high value GDEs. Together, these measures would ensure protection of key values supported by the CLA's groundwater. This management approach should be informed by a continuing program of inter-disciplinary science and community consultation, focusing on groundwater requirements of GDEs, and modelling to determine relationships between flows to these, extraction volumes, gradients, and time.

Knowledge gaps which should be addressed urgently include better qualitative and quantitative information on inter-basin and inter-aquifer flows (topics currently being investigated), better quantification of flows from the CLA and other aquifers to springs and streams (including those that have been less studied than Mataranka Thermal Pools and the Roper River), and eco-hydrological studies (including more extensive stygofauna surveys). These studies should determine the groundwater levels, flow rates and quality required to sustain key environmental and cultural values, as well as possible downstream consequences of reduced spring flows, river baseflows and groundwater throughflows of various magnitudes. Understanding what community stakeholders consider to be acceptable risks and impacts, and making public all relevant supporting scientific data and analysis informing WAP rules, should form part of the process of determining extraction rate caps and triggers. There is also a need to consider climate change and variability, with mechanisms to account for this built into long-term integrated water resources management.

Keywords: Groundwater sustainability, Cambrian Limestone Aquifer, Groundwater Recharge, Sustainable Yield, Groundwater Dependent Ecosystems, Cultural Value of Water, Northern Territory.

Cover Image: Pandanus species at Bitter Springs, Elsey National Park, Northern Territory, Australia. Source: Wikimedia Commons.

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Introduction

This report, prepared at the request of Environment Centre NT, is designed to provide a concise, up-to-date review of literature and technical information about the Cambrian Limestone Aquifer (CLA), and current groundwater policies in the Northern Territory, in order to:

a) Consider the adequacy of current groundwater licensing arrangements under the *Water Act* – with a specific focus on the use of the Top End and Arid Zone contingent rules in water planning, and other proposed management rules in draft Water Allocation Plans

b) Make recommendations regarding the determination of sustainable yields and other management rules for Water Allocation Plans, and other relevant policies governing groundwater licensing within the CLA and Beetaloo sub-basin.

Recent groundwater licensing decisions and challenges to these[1] highlight that there is ongoing debate regarding the above issues, and a need for clear, scientifically informed analysis of the most appropriate mechanism(s) to ensure protection of groundwater dependent environmental, cultural, and economic values. The Pepper inquiry into Hydraulic Fracturing in the NT highlighted significant risks associated with the groundwater licensing arrangements in place at the time of the inquiry; these arrangements have remained largely un-changed since then. Recent licensing decisions signal an intent to apply the Arid Zone contingent rules (or similar management approach) over a larger geographic extent than has previously occurred, warranting thorough review of the potential risks and implications of this. Draft water allocation plans also include other methods to determine estimated sustainable yields within plan areas, based on recharge rates (which may or may not be protective of groundwater-supported values). This report delves into these issues and other knowledge gaps highlighted in the Pepper Inquiry and makes recommendations attempting to address these.

Appendix A lists the four main tasks/questions ECNT requested be addressed in this report. The subsequent structure of the report (in four sections) corresponds with these four topics. Subsequent to the commissioning of the report, ECNT also requested that the proposed groundwater management rules put forward in the draft Georgina Wiso WAP – released to the public in November, 2022 (Northern Territory Government, 2022a), be analysed and discussed (and this is done throughout the report).

The report draws upon literature that includes both technical work commissioned by or conducted within Northern Territory government agencies, as well as peer-reviewed scientific literature, including reports by national science agencies (e.g. CSIRO and Geoscience Australia) and academic institutions (e.g., relevant peer-reviewed journal papers).

[1] E.g., NT Land Corporation, application KG08988; Fortune, groundwater extraction licence WDPCC10000

1. Hydrogeology of the Cambrian Limestone Aquifer

a) Thickness, structure and properties

The Cambrian Limestone Aquifer (CLA) is an extensive carbonate aquifer underlying much of the Northern Territory to the north of Alice Springs and south of Katherine, encompassing most of the Barkly Tableland and Sturt Plateau. The aquifer system occurs within three major sedimentary basins; Daly, Georgina and Wiso (Fig. 1). The division between these three basins hosting the CLA corresponds with the presence of basement highs in the underlying rocks (at the basins' edges), above which the CLA aquifers thin and occur relatively close to the surface (e.g., Fig. 2). These basement highs are not complete hydrogeological or hydraulic boundaries; as such, there is some connectivity between the basins, with groundwater flowing from the southern two (Georgina and Wiso) providing inflows to the northern basin (Daly), in accordance with regional groundwater flow gradients (Tickell and Bruwer, 2017; Evans et al., 2020; Oberprieler et al., 2021). The primary limestone aquifer units of the CLA have different names within the three basins (Table 1):

Table 1: Major Cambrian Limestone Aquifer (CLA) units across the three major sedimentary basins (after Tickell and Bruwer, 2017; Bruwer and Tickell, 2015 and Evans et al., 2020).

Basin	**Name of main CLA aquifer units (Upper & Lower)**	**Comment on usage/aquifer potential**
Daly	Jinduckin Formation/Oolloo Dolostone (upper)	A minor aquifer that is thin or absent in much of the basin
	Tindall Limestone (lower)	Major CLA aquifer in the Daly Basin. Equivalent to Gum Ridge Formation (Georgina) and Montejinni Limestone (Wiso)
Georgina	Anthony Lagoon Formation (upper)	Locally high-yielding aquifer, utilized for stock watering
	Gum Ridge Formation (lower)	Thick, extensive and locally high-yielding limestone aquifer, less utilized than Anthony Lagoon Formation due to depth, but considered prospective as a water source
Wiso	Hooker Creek Formation (upper)	Local confining layer and/or aquifer depending on lithology.
	Montejinni Limestone (lower)	Major CLA aquifer in the Wiso Basin. Equivalent to Tindall & Gum Ridge Formations

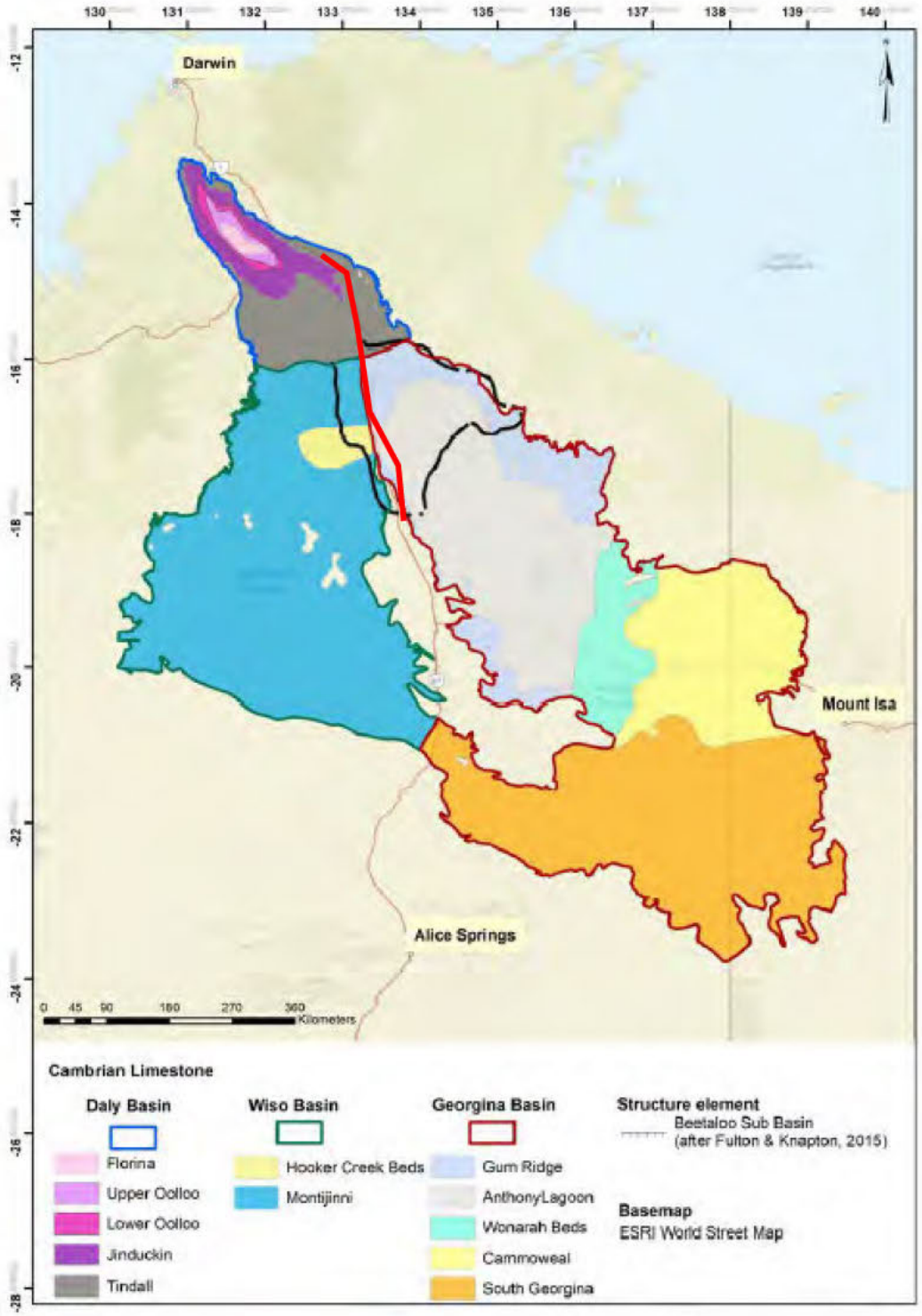


Figure 1: Map showing the three sedimentary basins hosting the Cambrian Limestone Aquifer (CLA) along with the outcrop geology. Modified from Deslandes et al., 2019. Red line shows approximate cross section location for Figure 2 (from Bruwer and Tickell, 2015).

The CLA has outcrops or sub-crops near the surface over significant areas in all three basins (notably at Mataranka, and the southern Wiso and Georgina Basins) but it is generally buried beneath younger sedimentary rocks from the Cretaceous period (Knapton, 2020). There is a time gap of approximately 400 million years between the Cambrian and Cretaceous rocks, and the boundary between the CLA and Cretaceous comprises a weathered erosional surface developed during this time. Significant karst features (sinkholes, caves and other secondary

porosity) also developed in the limestone. The boundary permits diffuse leakage of rainfall recharge to the CLA, where the Cretaceous cover is thin (Bruwer and Tickell, 2015).

The CLA is underlain by older Cambrian volcanic rocks (e.g., the Antrim Plateau basalts), and below this, Proterozoic sedimentary rocks, including those of the Beetaloo Sub-basin (e.g., the Roper Group) which host extensive oil and gas deposits (Evans et al., 2020). Together, the Cretaceous, Cambrian, and Proterozoic geological units form a thick sequence (up to 5 km) of stacked sedimentary rocks, including multiple aquifer and aquitard units. The extent of vertical connectivity between the CLA and underlying rocks is a focus of recent and current research programs, as recommended by the Pepper Scientific Inquiry - e.g., through the Strategic Regional Environmental Baseline Assessment (SREBA) program. The most recent reports from these programs note that inter-basin and inter-aquifer connectivity occur, but are generally still not well characterized (Lamontagne et al., 2021; Frery et al., 2022). These studies have found evidence from environmental tracers and geophysics of deep groundwater flow reaching shallow aquifers and/or the surface, e.g., at Mataranka springs (Lamontagne et al., 2021).

Aquifer thickness and structure

The CLA ranges in thickness from approximately 20 to 80 m above basement highs where it outcrops or sub-crops near the surface (including near the Roper River and Mataranka springs), to over 400 m at its thickest extent within the Georgina Basin, comprising the Anthony Lagoon and Gum Ridge formations (Tickell and Bruwer, 2017). Throughout most of the Daly, Georgina and Wiso basins, the CLA ranges between approximately 100 to 300 m thick and can be described as a semi-confined to unconfined aquifer. An example cross-section showing the Tindall Limestone and Gum Ridge Formations (lower CLA units in the Daly and Georgina basins, respectively), overlying and underlying geological units across the Daly/Georgina boundary, is shown below:

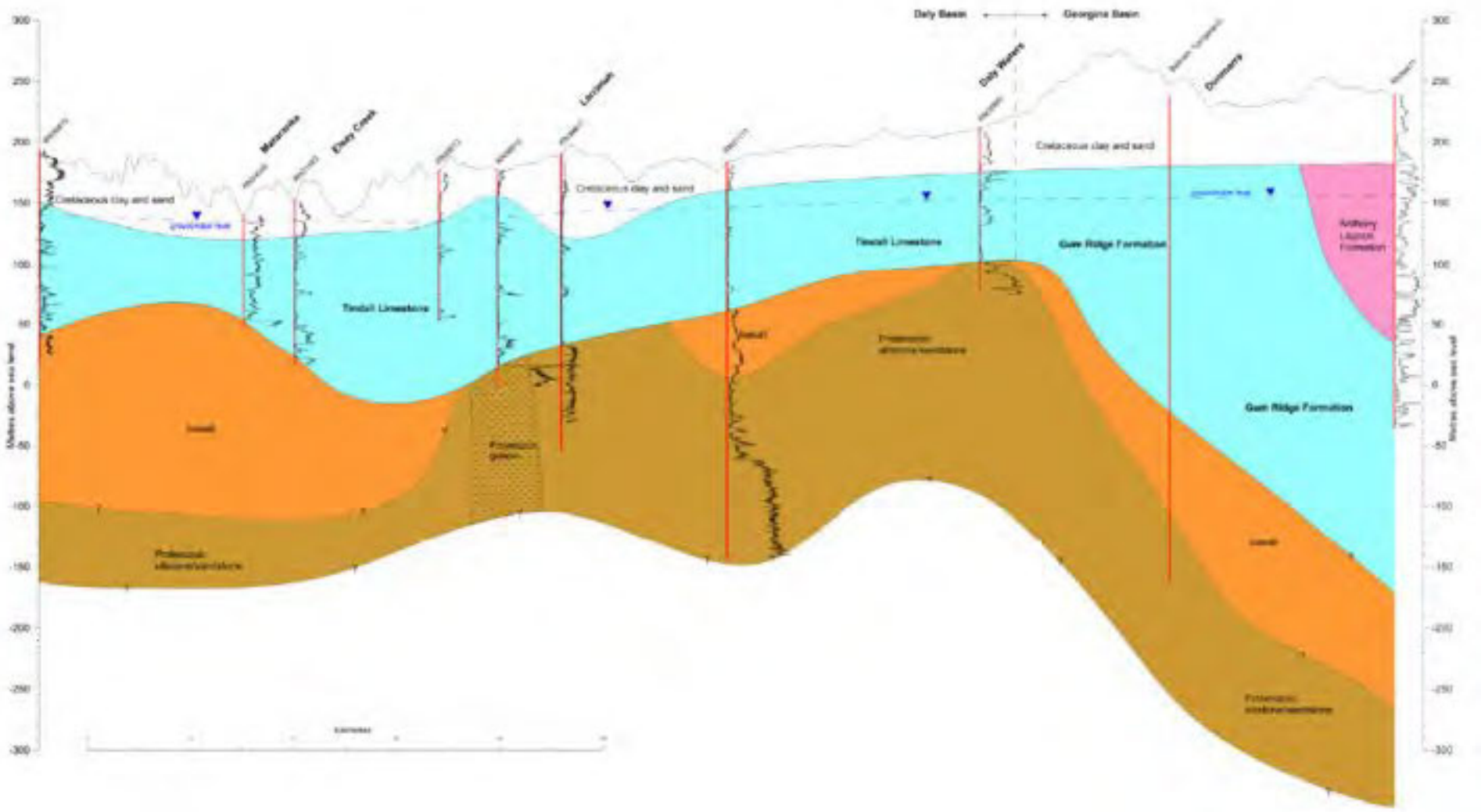


Figure 2: Cross section of the southern Daly and northern Georgina Basin, showing estimated thickness of the CLA, Cretaceous cover, and underlying Cambrian and upper Proterozoic rocks (From Bruwer and Tickell, 2015). Approximate cross section location indicated on Fig. 1.

Aquifer properties

A program of pumping tests has been carried out to assess the CLA's potential bore yields and hydraulic properties in the Daly and Georgina basins. This has determined that aquifer transmissivity values – which determine how much groundwater can be readily extracted and the extent of drawdown in response to pumping - range between relatively low values (~5 m^2/day) up to very high values (over 45,000 m^2/day). These data are summarized in Table 2:

Basin	**Unit**	**Range of transmissivity values (m^2/day)**	**Estimated groundwater storage capacity (GL)**
Daly	Tindall Limestone (lower)	100 to 47,400	28,200 to 56,400
Georgina	Anthony Lagoon Formation (upper)	13 to 8200	1,766,000 to 3,532,000 GL
	Gum Ridge Formation (lower)	5 to 3100	52,500 to 157,500 GL
Wiso	Hooker Creek Formation (upper)		
	Montejinni Limestone (lower)	3 to 9480	

Table 2: Summary of estimated aquifer transmissivity values for main CLA units (after Bruwer and Tickell, 2015; Tickell and Bruwer, 2017; Knapton, 2020).

Transmissivity values of above ~500 m^2/day are generally considered permeable and prospective for development of an aquifer as a water resource[2]. As such, significant portions of the CLA would be considered high-yielding. However, transmissivity values are highly variable throughout the region, e.g., in areas of the Georgina Basin where the Anthony Lagoon Formation comprises low-permeability siltstone (between limestone layers) bores are low-yielding with T values < 50 m^2/day. Knowledge of aquifer hydraulic parameters within the Wiso Basin (e.g., Montejinni Limestone) is relatively limited (see Table 2), as a significant program of pumping tests and related studies has not (to our knowledge) been reported.

Storage capacity

Various estimates of the total amount of groundwater in storage within the CLA have been given, as noted in Table 2. These estimates should be interpreted with caution for two reasons:

1. The CLA is not a 'standard' porous medium (with uniform distribution of void space in which groundwater can be stored). Instead, much of the porosity is secondary, relating to karstic features (sinkholes, dolines) and fracturing. How much water in storage is available for extraction is unlikely to be well described by these bulk estimates. For example, effective porosity values of up to 40% (cited in Tickell and Bruwer, 2017) for the Gum Ridge Formation may over-estimate the availability of water that can be readily extracted.

[2] For example, see Science Direct topic entry under Transmissivity: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/transmissivity

2. Aquifers should not be described in terms of their total storage when considering sustainable yields or 'safe' extraction rates (this topic is covered in detail in Sections 2 and 3 of this report). It is the water flows to and from an aquifer sustaining other aspects of the water cycle and dependent values (e.g., groundwater flows to streams, springs and other aquifers), that is the most important factor in assessing the sustainable yield from an aquifer (not storage volume) (Theis, 1940; Alley et al., 1999; Ponce, 2007). These flows are normally very small in comparison to the total water in an aquifer's storage; extracting even small proportions of overall storage can have significant water cycle consequences (e.g., reduced baseflows and/or loss of groundwater dependent ecosystems). Viewing the aquifer as a single connected 'bucket' of stored water that can be extracted without impacting the broader water-cycle, risks serious harm to water users and the environment (Alley et al., 2002; Bierkens and Wada, 2019).

b) The water balance of the CLA and connections to the broader water cycle

Groundwater Recharge

Groundwater recharge - defined as water that crosses the water table, adding to groundwater stored in an aquifer (Healy, 2010) may take place through a range of mechanisms, e.g., diffuse rainfall infiltration across a wide area vs. focused recharge below specific landscape features; continuous recharge vs. episodic 'event-based' recharge. Direct recharge – i.e., rainfall percolation below the soil zone to the water table, to the CLA is thought to be restricted to areas where the Cretaceous rocks covering the aquifer are thin or absent (Fig. 3). Other recharge mechanisms that have been identified include macropore flow (through large surface cracks) stream and lake water leakage, including surface water losses to karstic features (e.g., sinkholes and dolines) (Bruwer and Tickell, 2015; Tickell and Bruwer, 2017; de Caritat et al., 2019; Deslandes et al., 2019). The latter mechanisms are not well quantified throughout the CLA, though recent environmental tracer sampling by Deslandes et al (2019) allowed for approximate quantification of diffuse (rainfall seepage) and preferential (sinkhole) recharge in certain areas (see Table 3). Based on tritium data, point-based diffuse recharge rates were estimated to be between ~1mm/yr and 30 mm/year, generally increasing from south to north, in accordance with increasing rainfall and decreasing ET rates, while preferential recharge through sinkholes was estimated to occur at significantly higher rates (>100 mm/year) in local areas. Crosbie and Racchakonda (2021) derived similar overall recharge estimates based primarily on chloride data, while De Caritat et al (2019) also identified areas of the Wiso Basin where leakage from surface water bodies (Lake Woods and Newcastle Waters Creek) is the predominant recharge source. They noted Tarrabool Lakes to be a significant recharge feature to the Georgina Basin.

Bruwer and Tickell 2015 estimated recharge to the Daly Basin CLA (Tindall Limestone) to be approximately 330 GL/yr, based on water table fluctuations, Chloride mass balance, and numerical modelling. All these methods are acknowledged to have issues/uncertainties, but the use of multiple lines of evidence provides some level of confidence in the magnitude of the estimates. Tickell and Bruwer, 2017 used chloride data from precipitation and groundwater to estimate recharge to the two major CLA units in the Georgina Basin (Gum Ridge and Anthony Lagoon Formations). These were estimated to be approximately 1 to 10 mm/year on a point basis, which is approximately 0.2 to 3% of yearly rainfall. Quantifying these estimated rates across the extent of the basin's major recharge areas (see Fig. 3

below), results in overall recharge estimates of approximately 20 to 180 GL/year for the Gum Ridge Formation, and 50 GL/year for Anthony Lagoon Formation (Table 4).

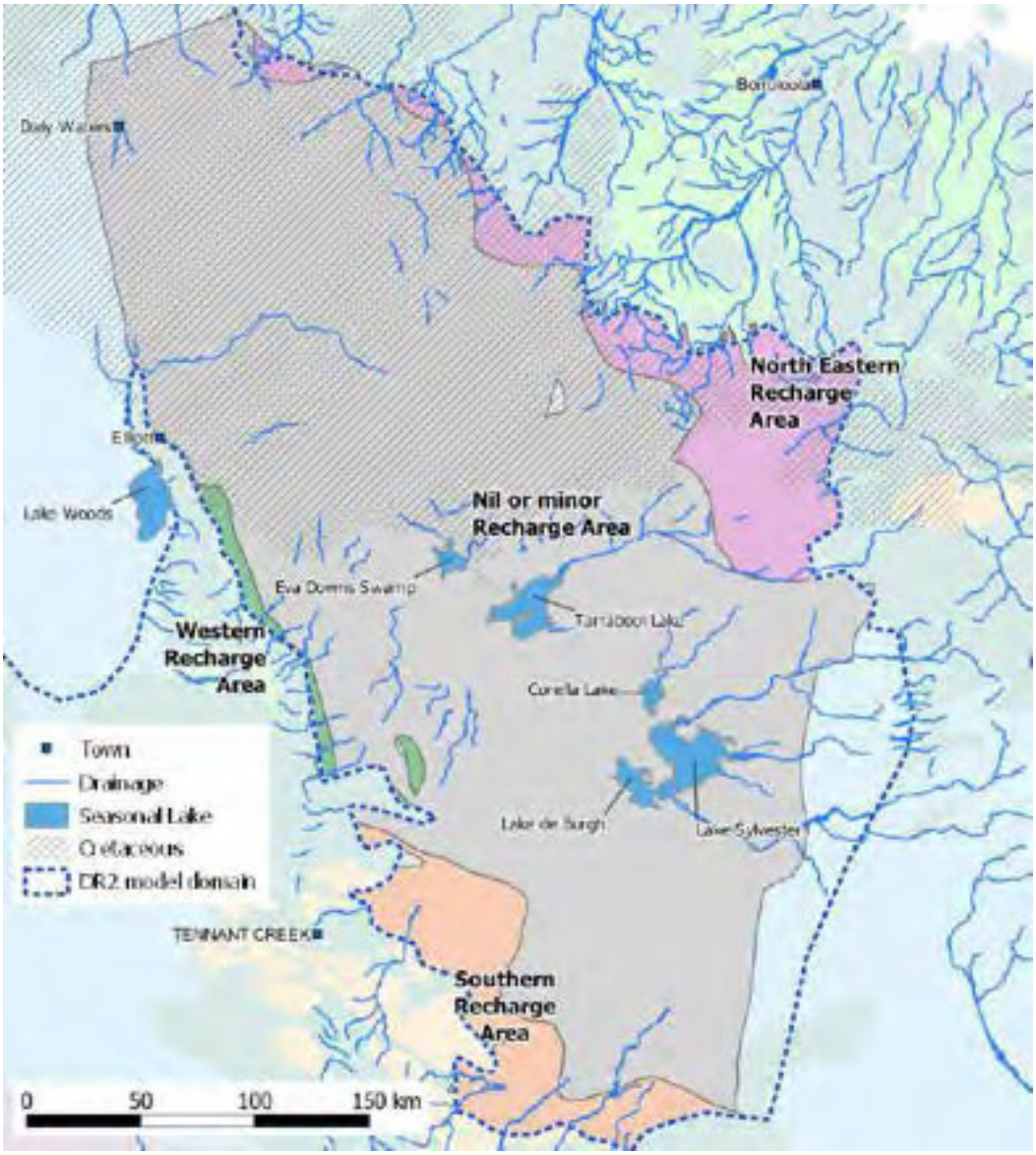


Figure 3 – Mapped or inferred groundwater recharge areas for the Georgina Basin (From Knapton et al., 2020, after Tickell and Bruwer, 2017).

Knapton et al., (2020) reviewed earlier estimates of recharge in the CLA to inform coupled surface-groundwater modelling using MIKE-SHE and FEFLOW. MIKE-SHE estimates recharge based on rainfall, evapotranspiration, vegetation and soil properties (allowing incorporation of preferential flow through macropores). Based on this approach, Knapton et al (2020) estimated recharge to the Georgina basin to be ~315 GL/yr, considerably higher than field-based estimates of Tickell and Bruwer (2017). Sanford (2002), Scanlon et al. (2002) and others have noted that caution is required when using numerical models and/or water balance estimates (with recharge calculated as the residual of other water balance terms) to estimate groundwater recharge. As a generally small part of the water budget, there are significant uncertainties with such estimates, and ground-truthing with field data is essential. Recharge in the Mataranka zone of the Daly Basin was estimated by Knapton (2020) at ~177 GL/year, in line with earlier estimates by Bruwer and Tickell (2015).

Hydrograph analysis in the Georgina Basin (Tickell and Bruwer, 2017) shows that recharge to the southern CLA aquifers (Georgina and Wiso basins) is mostly associated with rare, intensive wet periods, when 5-year moving average rainfall exceeds the long-term average. Major water table rises, indicating significant recharge, have been recorded only twice since monitoring began; in the mid-1970s and early 2000s. Recharge is likely to be well below the long-term average in most years, but substantially above long-term averages only during such rare wet events.

The recently released draft Georgina Wiso WAP estimates recharge rates to the Georgina and Wiso Basins to be approximately 660 GL/year; i.e., significantly higher than the previous model-based estimates outlined in Table 3. The 660 GL/year value is based on updated coupled surface water-groundwater modelling - the same model reported in Knapton, (2020). The estimate is however nearly double the recharge reported for the Georgina Basin in the previously documented modelling. This is likely due to the use of the most recent 50 year-period of data (1970 to 2020, a relatively wet period), as opposed to the full length of available climate records – Knapton, (2020) used the longer period of 1900 to 2019 climate data. Notably, the majority (two thirds) of the recharge contributing to the overall total over the revised modelled conducted for the draft WAP occurred during 1974, an extremely wet year which saw an estimated 21,280 GL of recharge. There is very little data to indicate the mechanism or geographic extent of this large, episodic recharge event, nor any indication as to how frequently such events may recur. As such, the estimation of average recharge in the draft WAP, is very heavily dependent on a single recharge event nearly fifty years ago, for which data are mostly lacking. This is critically important when assessing whether extracting a fraction of the averaged recharge rate derived using the model – e.g., 40%, as proposed in the plan – can be considered appropriate as a sustainable yield (see further discussion in section 2 and 3 below).

In recent years, estimation of groundwater recharge has also been attempted using satellite remote sensing methods, in particular the Gravity Recovery and Climate Experiment (GRACE), launched by NASA in 2002. The use of these data is still generally considered to require careful ground-truthing, as there are multiple sources of uncertainty and potential error (e.g., Chen et al., 2016). In the Murray Darling basin and elsewhere, the agreement between satellite and in-situ data from monitoring bores suggests GRACE data can track groundwater dynamics (e.g., Rateb et al., 2020; Chen et al., 2016) with limited uncertainties compared to outputs from models and other sources (see Scanlon et al., 2002). Estimation of recharge and/or groundwater storage changes with GRACE is only feasible over large geographical areas, as the satellite data have limited local-scale resolution.

Preliminary analysis in this report shows that the large scale of the CLA allows for meaningful use of GRACE to examine recharge rates and water balance trends (Figure 4 and Table 3). Annual recharge in the Daly Basin was estimated from GRACE data for 2003-2016 based on the difference between maximum groundwater depth observation in a particular year and the shallowest observation in the following year. Soil moisture, derived from the Global Land Data Assimilation System model (GLDAS-Noah), was subtracted from the overall GRACE signal for terrestrial water storage change. Preliminary recharge estimates using this method resulted in high rates (> 200 mm/yr) in the northern Flora River catchment, reducing gradually towards the south, and slightly reducing over time (Fig. 4b). Recharge in the Gregory River catchment ranged from 66-90 mm/yr and appeared to be slightly increasing with time. The recharge estimates broadly align with those proposed by Deslandes et al., (2019) and chloride mass balance data by Crosbie and Rachakonda (2021), though they are higher than previous estimates.

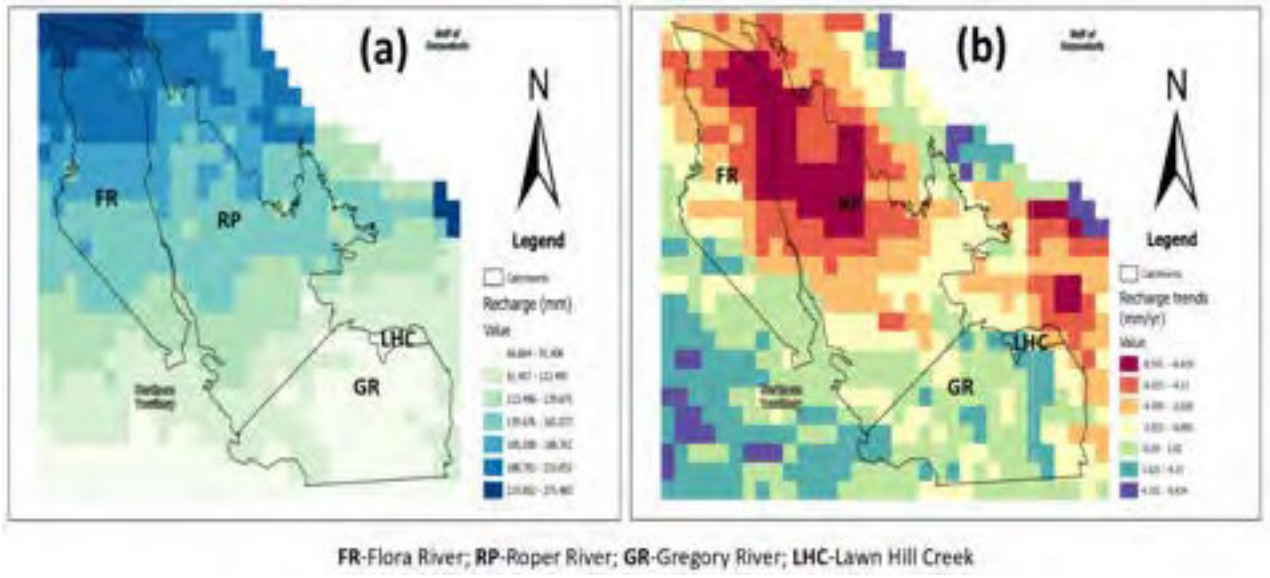


Figure 4 – Spatial patterns of annual groundwater recharge in four catchments of the Cambrian Limestone Aquifer estimated from the Gravity Recovery and Climate Experiment satellite (2003-2016). (a) Shows the average annual recharge and (b) the trends in annual recharge during the period. Data sourced and processed by C. Ndehedehe

This preliminary analysis indicates that, notwithstanding uncertainties relating to estimates of soil moisture, GRACE can be used as an independent line of evidence for recharge to the CLA, and to examine its responses to climate variability and water extraction. In the CLA, recharge is primarily being driven by annual rainfall and possibly also the strongly annual temporal patterns of surface water extent (de Caritat et al., 2019).

Table 3: Summary of recharge estimates for the CLA

Study	**Basin/Unit(s)**	**Point-based recharge rate estimates (mm/year)**	**Volumetric recharge rate (CLA)**	**Method(s) used**
Deslandes et al., 2019	Southern Daly (Tindall), Northern Georgina (Anthony Lagoon & Gum Ridge Fm),	1 to 25 mm/yr (diffuse, increase south to north); 140 to 190 mm/yr (preferential	Not quantified	Tritium, Chloride mass balance (recharge rate); CFCs, SF6 and noble gases

	Northern Wiso (Montejinni Lstone)	recharge through sinkholes)		(qualitative insights)
Bruwer and Tickell, 2015	Daly Basin / Tindall Limestone	8.7 to 28.5 mm/yr (in areas of shallow/exposed CLA)	Approx. 330 GL/yr (possible range from 286 to 722 GL/yr).	Water table fluctuations, Chloride mass balance, water balance, model
Tickell and Bruwer, 2017	Georgina Basin / Anthony Lagoon Formation	0.9 to 12.2 mm/yr (areas of shallow/ exposed CLA)	20 to 179 GL/yr (Gum Ridge Fm) 51 GL/yr (Anthony Lagoon Fm)	Chloride mass balance
Crosbie and Rachakonda, 2021	Entire CLA	5 to 156 mm/yr including: 5 to 18 mm/yr (Georgina); 9 to 31 (Wiso); 49 to 156 (Daly) (5^{th} to 95^{th} percentiles)		Chloride mass balance, constrained using baseflow separation and remote sensing data
Knapton et al., 2020	Georgina Basin & Daly Basin		315 GL/yr (Georgina); 177 (Daly)	Coupled ground-surface water modelling
Northern Territory Government, 2022a	Georgina & Wiso Basins		608.4 GL/yr (Georgina); 48 GL/yr (Wiso) (Additional estimates compiled in background report – NTG, 2022b)	Coupled ground-surface water modelling
This study (preliminary estimates only)	Daly Basin (Flora, Roper, Gregory River catchments)	174 mm, 87 mm, 84, and 144 mm for the Flora River, Gregory River, Lawn Hill Creek and Roper River catchments.	Not quantified	GRACE satellite data

Groundwater flow patterns

Regionally, groundwater flows from the southern parts of the Barkly Tableland, Sturt Plateau and Wiso Tableland (within the Georgina and Wiso basins) to the north, following the gentle decline in topography (Fig. 4). Flow patterns within the Daly Basin continue this northerly-directed flow-path within the Tindall Limestone, towards the Roper River and Mataranka Springs on the east of the basin, and towards the Flora River and associated springs on the western side of the basin (e.g., Top Springs). In the Daly Basin, there is also flow from the northern margins (near Katherine) towards the south, with groundwater flows again converging upon and discharging to the Mataranka Springs and Roper River (Fig. 4). At the northern extent of the Daly Basin, there is further northward-directed groundwater flow in the Tindall Limestone, which discharges into the Daly River through many springs (Fig. 4).

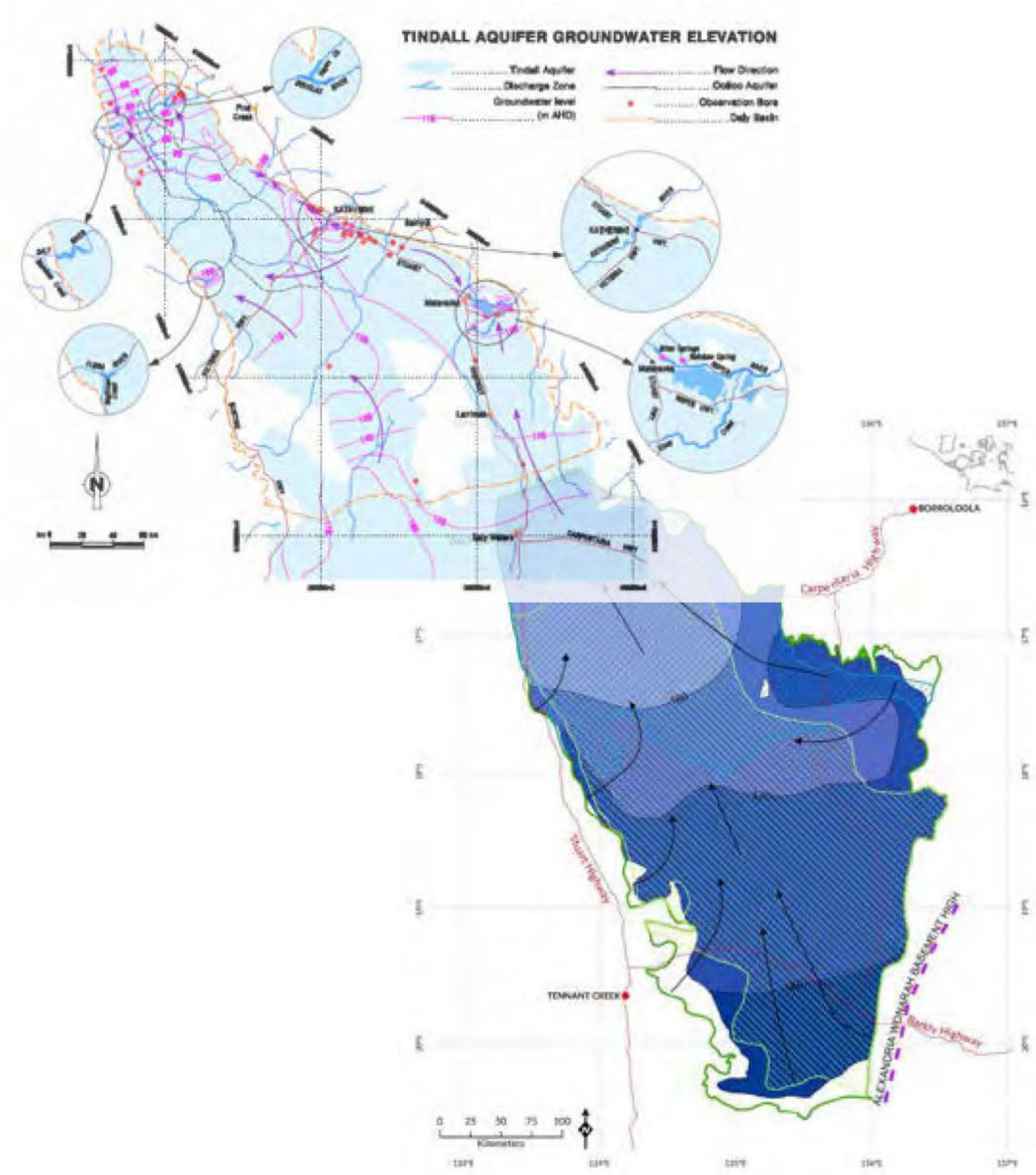


Figure 4 – Composite map of approximate groundwater level contours in equivalent Cambrian limestone aquifer units across the Georgina Basin (bottom image) and Daly Basin (top image). Maps from Tickell (2007) and Bruwer and Tickell (2015).

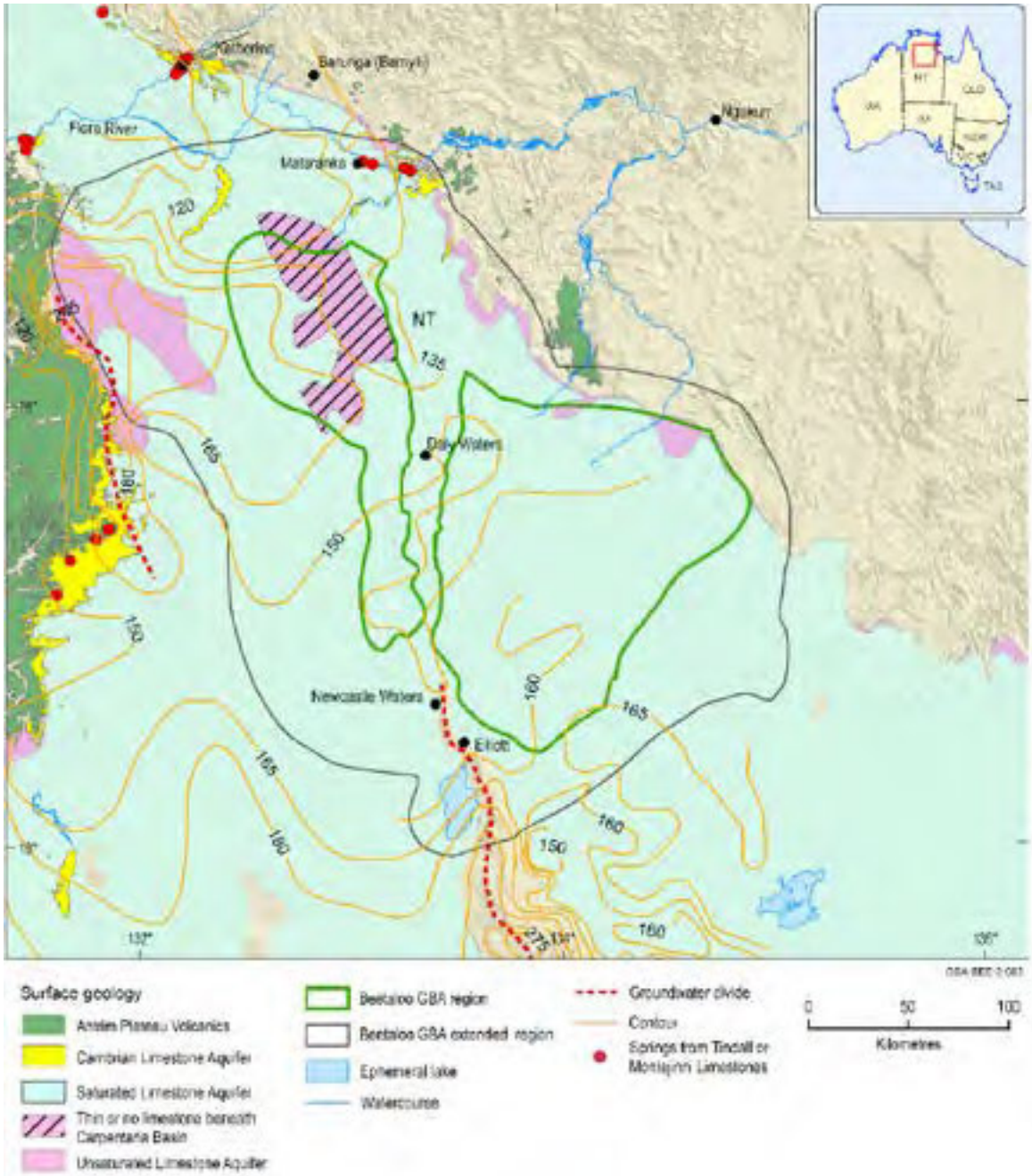


Figure 5: Approximate water level contours: Montejinni Limestone, Wiso Basin and Tindall Limestone, southern Daly Basin, with Beetaloo sub-basin indicated. From: Evans et al., (2020).

Throughflow between different CLA units in the three basins

The extent of connectivity along regional groundwater flowpaths, i.e., the amount of throughflow from the Georgina and Wiso basins into the Daly Basin along its southern boundary, and the importance of such throughflow (as opposed to more localized recharge), in sustaining fluxes and levels in the Tindall Limestone, remains a major knowledge gap (Evans et al., 2020). This has significant implications for how the CLA is likely to respond to groundwater extraction in different regions - i.e., the extent of localized vs. regional impacts. The groundwater contour patterns mapped and shown in Fig. 4 and Fig. 5 indicate that groundwater flow in the main CLA units continues from the northern extents of the Georgina and Wiso Basins into the Daly Basin, i.e., throughflow from the southern basins into the Daly. The mapping of stygofauna assemblages recently by Rees et al (2020) and Oberprieler (2021) indicated that there is a high degree of connectivity within the CLA across the three basins - if this was not so, more localized endemic stygofauna communities would be expected. This is further supported by similarities in the hydrochemistry of groundwater along flow paths that cross the basin boundaries (Evans et al., 2020).

Tickell and Bruwer (2017) note that despite the equivalence between the Tindall Limestone and Gum Ridge Formation across the Daly/Georgina basin boundary and regional flow directions, recharge and flow patterns are somewhat different in the two basins, and localised recharge and flow within each basin are also important:

> "There is a notable difference in the flow pattern in the Gum Ridge Formation compared to that in the Tindall Limestone, its equivalent in the Daly Basin. In the latter case, where the Formation outcrops along the basin margin, flow is parallel to the margin and groundwater discharges to streams which are generally perpendicular to the margin. In the Georgina Basin, groundwater levels are too deep to discharge to streams, so the flow pattern is basin-wards from the margins and then to the north-west." (Tickell and Bruwer, 2017)

On the basis of pumping test data, hydraulic gradients and aquifer geometry, Tickell and Bruwer (2017) estimated throughflow from the Georgina Basin (Gum Ridge Formation) to the Daly Basin (Tindall Limestone) to be approximately 2 GL/year. Knapton (2020) proposed somewhat larger estimates of groundwater throughflow from the Georgina to Daly basin, with 1.6 to 16 GL/yr transferring as throughflow (Figure 6). This is still a relatively small contribution to the Tindall Limestone's water balance in comparison to rainfall recharge within the basin itself (Table 4), however it may be important for sustaining water levels and flows through the Daly Basin. Carbon isotope dating also points to somewhat complicated relationship between groundwater flow patterns, recharge, and inter-basin connectivity:

> "From carbon isotopes, Suckow et al. (2018) noted that apparent groundwater ages became younger northward along an inferred regional flow path trend, from the Georgina Basin to Daly Basin. This is the opposite of what is usually expected, which is that groundwater becomes older along a confined flow path. One explanation for the apparent carbon age trend is that recent recharge is occurring in the northern part of the trend, with older groundwater at the southern end of the flow path in the Georgina Basin. Other interpretations and complicating factors, put forward by Suckow et al. (2018) are: there is not a continuous regional flow path (flow paths are more localised), unknown processes are influencing the carbon isotope results, or that flow velocity is high enough along the flow path that not enough time is available for significant radioactive decay to occur in carbon isotopic system." (Evans et al., 2020).

Knapton (2020) summarised a basic water balance for the Georgina & Daly basins, encompassing throughflow and estimates of groundwater discharge to the Roper River and Mataranka Springs, as outlined in Figure 6. Groundwater contour mapping shows that groundwater flow divides between and within the three basins are important controls on flow patterns and inter-basin connectivity, and that these are controlled by topography and geological structure (e.g., faulting); particularly in the Wiso Basin, where flow towards Top Springs on the western basin margin is important in addition to the northward directed flows into the Daly Basin towards the Flora River (Fig. 5).

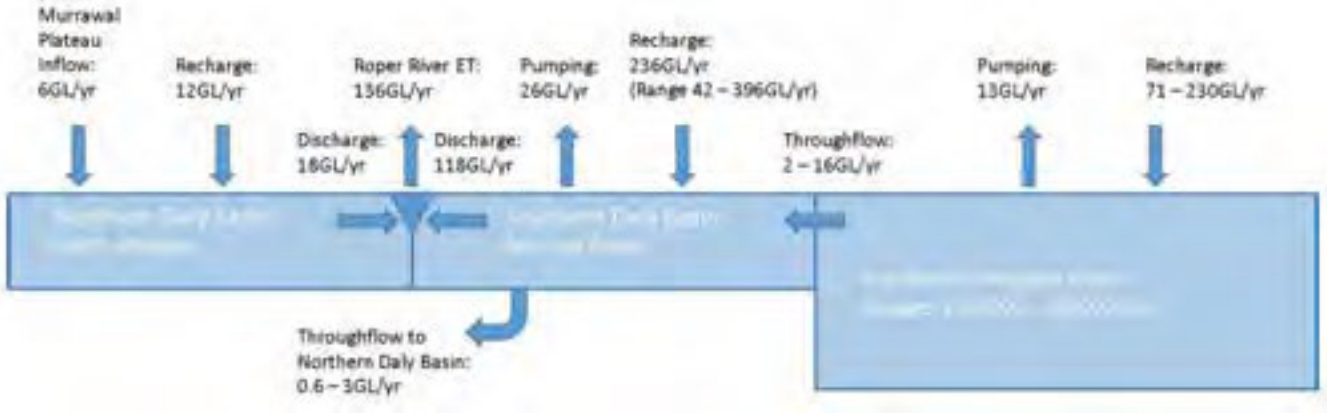


Figure 6: Indicative water balance for the Roper River basins encompassing estimated recharge, discharge and throughflow rates. From Knapton, (2020).

Groundwater discharge

Discharge of groundwater from the Tindall Limestone within the Daly Basin occurs to the Roper River and its southern tributaries – e.g., Elsey Creek, via springs (including Mataranka Thermal Pools) and diffuse discharge to the river channel along a significant length within the upper catchment (Figure 7). These flows make up a very significant proportion of the Roper and its tributaries' flow in the upstream section of the catchment, and support important Groundwater Dependent Ecosystems and cultural values (Jolly et al., 2004; Karp, 2008; Barber and Jackson, 2011; Bruwer and Tickell, 2015; Lamontagne et al 2021). CLA groundwater discharge to the surface has been estimated to be approximately 3 to 4 m^3/second downstream of the Mataranka springs (Knapton 2006; Fulton and Knapton, 2015), equating to approximately 260 to 345 ML/day, encompassing flow from both north and south (Evans et al., 2020). Springs along the Flora River on the western side of the Daly Basin receive approximately 2.3 m^3/second of discharge at the end of the dry season and the river is estimated to gain approximately 2 to 5 m^3/second of flow from the Tindall Limestone (see Evans et al., 2020, citing Knapton, 2006). Further information about the flows from the CLA to the surface and the values they sustain are discussed in further detail in section 1c, below.

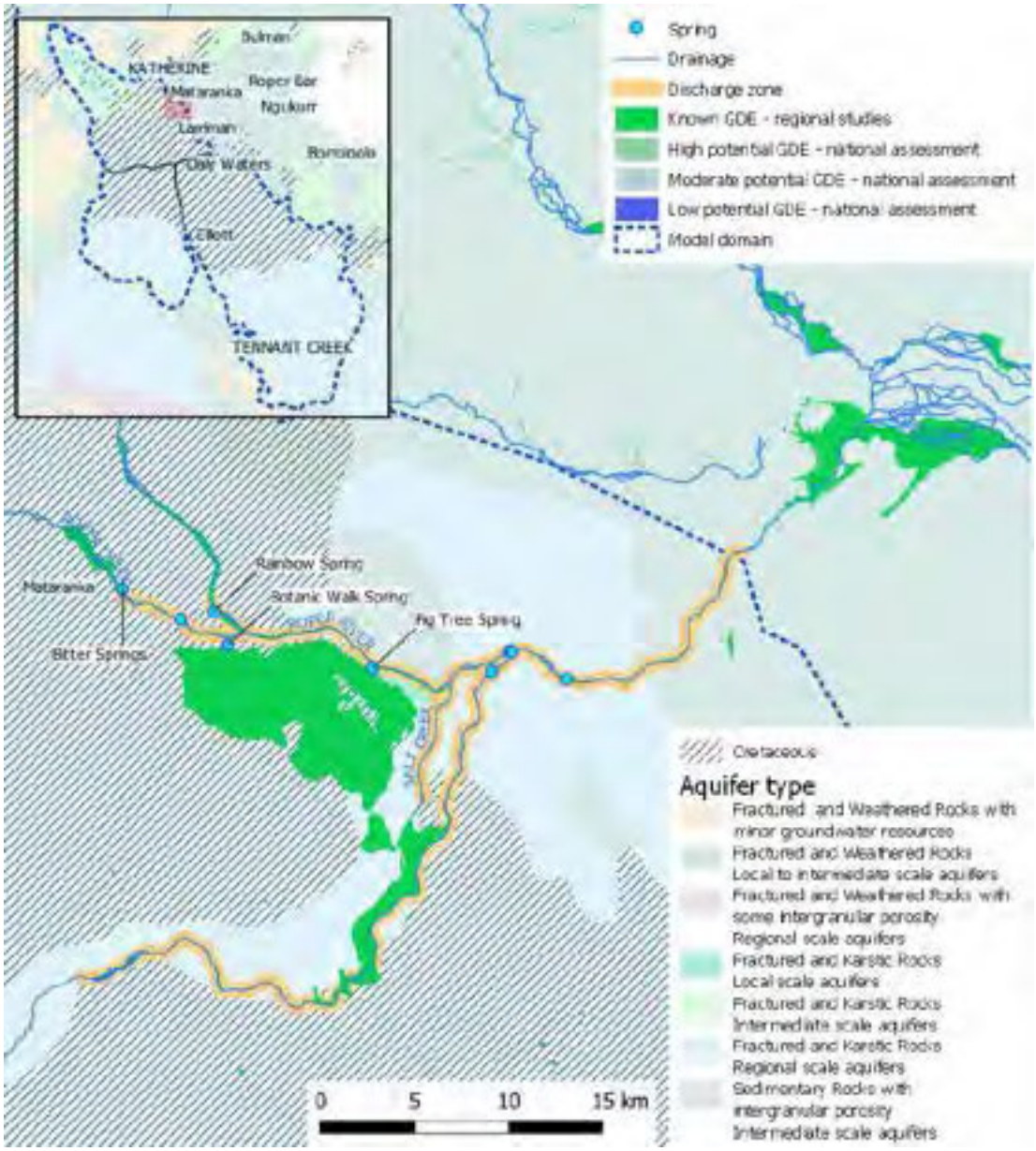


Figure 7 – Mapped locations of groundwater dependent ecosystems receiving discharge from the CLA in Mataranka region (From: Knapton, 2020). The major tributary to the south is Elsey Creek.

Additional groundwater discharge from the CLA is associated with evapotranspiration by groundwater dependent vegetation, in areas of shallow water table (Knapton, 2020).

In the Georgina Wiso basin, there is very limited understanding of groundwater discharge mechanisms. The draft Georgina Wiso basin WAP hypothesises that groundwater outflow from the CLA in these two basins only takes place through (relatively small volumes) of groundwater throughflow to the Daly Basin to the north, with no additional groundwater discharge through ET or groundwater flows to springs and other surface features. This is premised on the assumption that CLA groundwater levels are uniformly deep below ground level (difficult to assess currently, due to a lack of comprehensive monitoring bore coverage), and that vegetation communities are not able to access groundwater from deep water tables. This matter requires further careful analysis. The idea that recharge to the aquifer is not balanced by comparable amounts of groundwater discharge would be unusual for a large, relatively un-developed aquifer system. Typically, aquifers that have limited groundwater extraction are thought to come to a long-term equilibrium where recharge + inflow is approximately balanced by discharge + outflow (Theis, 1940; Alley et al., 1999).

Evans et al., (2020) note that CLA groundwater may provide flows that sustain Top Springs on the western side of the Wiso basin; however, field studies are lacking to verify this or

determine the rate(s) of discharge. The water level mapping presented by Evans et al., (2020) and other Bioregional Assessment reports also indicates that there are areas where CLA groundwater levels are likely to be within 20 m of the surface. Whether there are deep-rooted vegetation communities that are adapted to utilise such groundwater (e.g., *Acacia* species able to grow deep tap-roots, Lamoureux et al., 2016) is not known. Further field evidence is clearly needed to resolve the above issues and determine where and how much groundwater discharge occurs from the Georgina and Wiso basins, and what values are sustained by these flows.

Timescales of flow and aquifer response times

The timescales of groundwater flow between recharge and discharge areas within the CLA are not well known, nor is it well understood how long the system may take to reach a new equilibrium in response to significant disturbance, such as a major and rapid increase in groundwater extraction rates, or a step-change in the regional climate conditions. Analysis of basin time-constant (τ) as per equation 1 below, is one way to approach this question (Schwartz et al., 2010; Currell et al., 2016). Numerical modelling can also estimate these time-dependent responses and lags.

$$\tau = \frac{L^2 S_S}{K}$$

$$\tau_{step} = \frac{L^2}{D_h}$$

Where L = length of the flow system, K = hydraulic conductivity [L/T], Ss = Specific Storage (dimensionless), Dh = Hydraulic diffusivity (transmissivity/storativity) [L^2/T]. Value of τ (in units of time) represent approximate period required for a groundwater flow system to re-equilibrate following a major hydrological change/disturbance. After Currell et al., 2016.

Based on preliminary analysis of aquifer dimensions and hydraulic properties (Table 2), time constants on the order of 500 to 50,000 years would apply to the Georgina and Daly Basin flow systems (assuming a continuous, connected flow path across the length of the basin(s), see Fig. 4). The aquifer system(s) would be expected to take hundreds to tens of thousands of years to reach a new steady-state (where inflows and outflows reach a stable equilibrium) following a major hydrological change. This does not mean that increasing rates of groundwater extraction in the short term would take this length of time to impact on groundwater levels and discharge to the surface - such impacts would begin to manifest immediately close to the points of extraction and spread over time throughout the system as it re-equilibrates. Rather, τ values indicate the timescale required for the full effects of a major hydrological change to manifest. These concepts are discussed further in Section 2. In the numerical model for the Daly basin used by Bruwer and Tickell (2015) to assess potential impacts of increased groundwater extraction on Roper River baseflow, it took approximately 300 years for a new steady state to be reached, following a new wellfield extracting 20% of estimated recharge. Decreases in discharge to the river began to occur rapidly, exceeding 15% within 25 years. This timeline is consistent with earlier modelling by Knapton (2004).

Radiocarbon and other environmental tracer data in Deslandes et al., (2019) also give an indication of timescales of recharge, throughflow and discharge in the CLA (Figure 8); however, caution must be applied in the estimation of 'age' of groundwater, as groundwater isotopic data appear not to follow a clear horizontal and/or vertical flowpath (such as a piston flow or exponential piston flow model, for which calculation of groundwater velocities can be achieved). Most ^{14}C results from groundwater samples in the CLA range from 10 to 100 percent modern carbon (where 100 pmC represents modern/recent recharge), and also contain tritium (albeit at relatively low concentrations) 'excess air' and modern gases such as SF6. The detection of these 'young' groundwater age tracers indicates active recharge throughout much of the region, which possibly overprints groundwater 'ageing' along regional flowpaths (Deslandes et al., 2019).

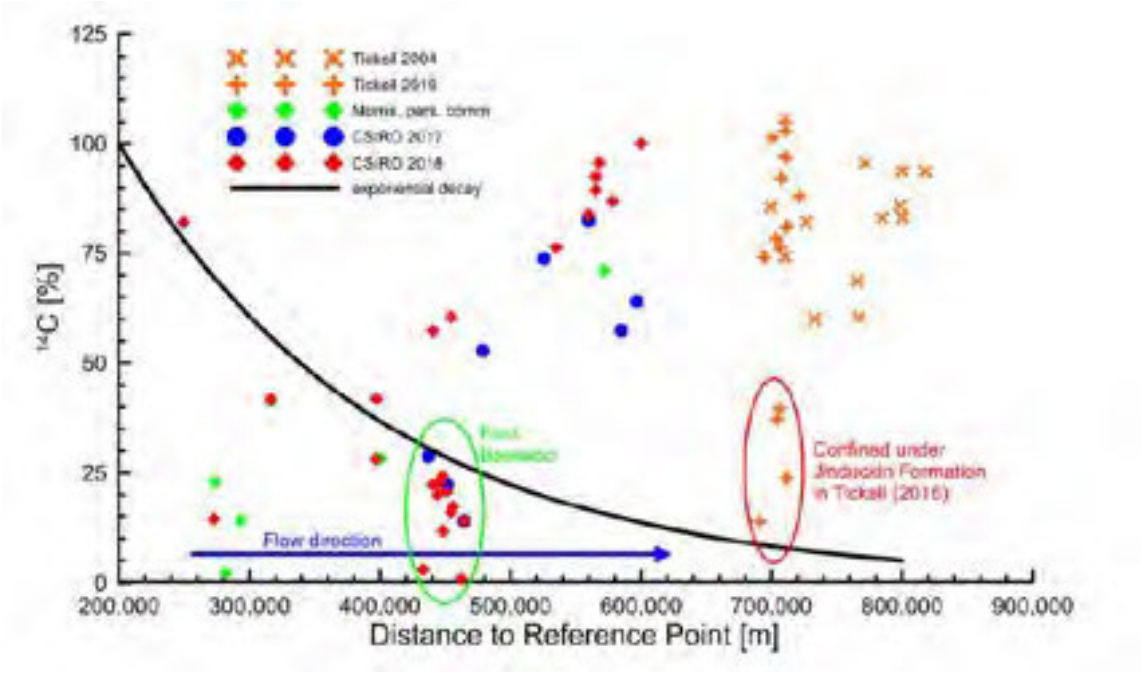


Figure 8: Summary of radiocarbon data from the CLA, from Deslandes et al., (2019).

c) The dependencies on the key groundwater systems from hydrological, environmental and cultural perspectives.

In the Daly Basin, discharge of water from the Tindall Limestone to the Roper River is a significant proportion of the river's flow in the upper catchment, and supports important Groundwater Dependent Ecosystems (Karp, 2008; Bruwer and Tickell, 2015; Evans et al., 2020; Lamontagne et al 2021). These groundwater flows sustain the river and its tributaries through dry periods – i.e., the river is fully dependent on groundwater following periods of low rainfall. Discharge from the CLA is also the predominant source of water sustaining the Mataranka Springs, which flow to the Roper River in its headwaters. Karp, (2008) explained:

> "The springs in the Roper start from the upstream junction of the Waterhouse River and Roper Creek (which join to become the Roper River) and extend east to the edge of the limestone basin. This region is the most significant in terms of groundwater and surface water interactions with the Mataranka Basin providing much of the base-flow in the Roper River."

Locations of the Waterhouse River, Roper Creek and downstream section of the Roper River are shown in Figure 9; essentially this region is the beginning of the Roper River catchment, and thus discharge from the Tindall Limestone provides permanent flows at the source of the river, which sustain all downstream sections. Figure 7 also shows mapped areas of groundwater discharge in this area.

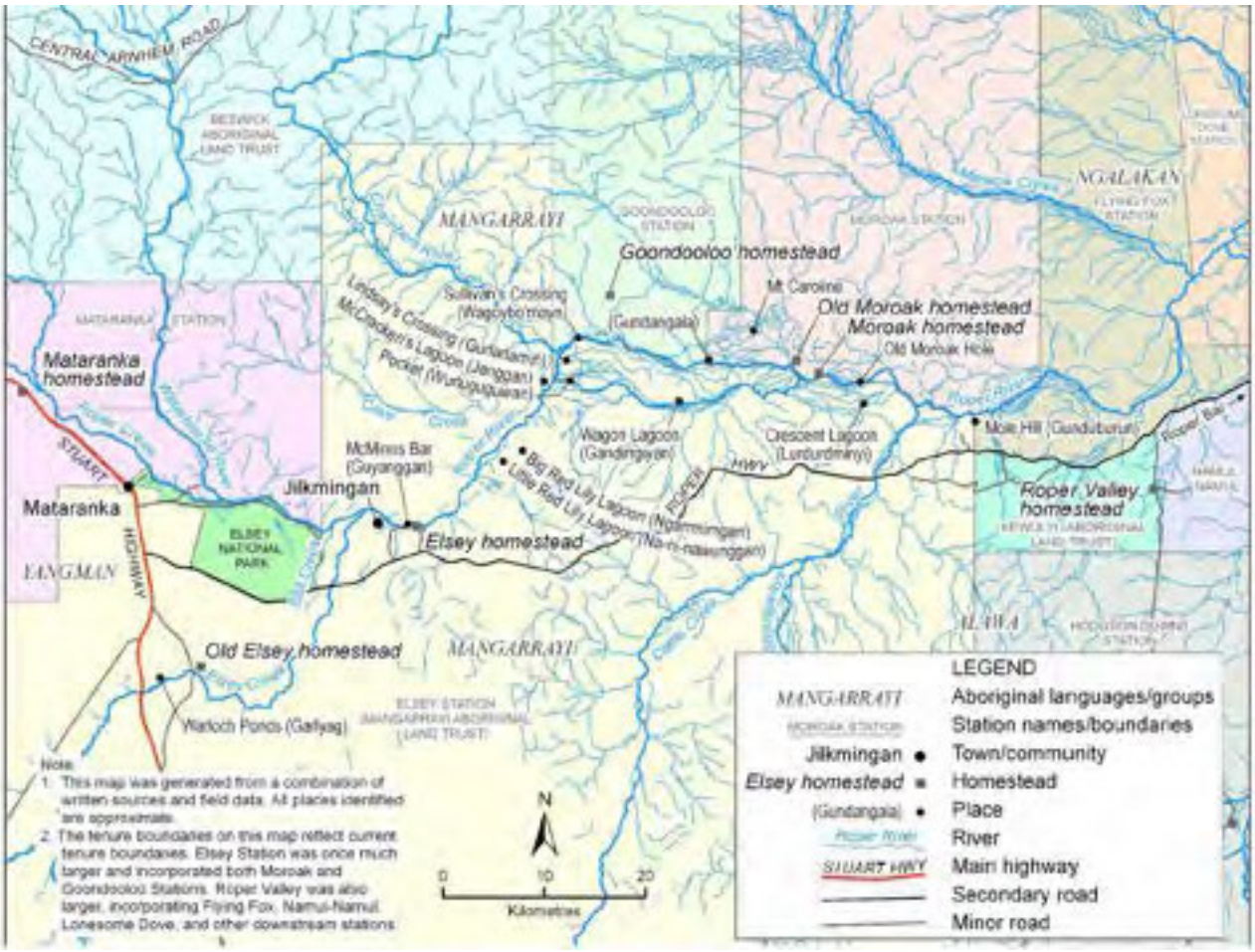


Figure 9: Detailed map of sites in the upper Roper River catchment (from Barber and Jackson, 2012).

Karp (2008) showed that the zone where the Roper River crosses the Tindall Limestone and receives discharge from the aquifer is associated with a sharp increase in river flows, which then decline gradually moving downstream, implying limited additional baseflow inputs to the river:

> "Clearly the karstic springs in the Tindall aquifer provide significant flow to the river in the Mataranka Basin with the rate of increased flow being high in this region. Similarly, immediately downstream of the Basin, the subsequent decrease in flow is significant and is associated with losses to swamps and wetlands such as Red Lily Lagoon and 57 mile Waterhole"

Karp (2008) further stressed the dependence of the river (including downstream sections) on Tindall Limestone groundwater discharge and management implications of this dependence:

> "Analyses of data collected during a comprehensive survey in October 1980 show only small changes in water quality in the non-tidal sections of the Roper River extending some 200 kilometres from the junction of Roper Creek and Waterhouse River to Roper Bar (Figure 4.13). **This suggests that during the dry season, the limestone aquifers in the Mataranka basin provide the main supply of water flow in the Roper River. Thus, the management of the groundwater resources in the Mataranka Basin is crucial to the viability of the downstream reaches of the Roper River**."

Source(s) of groundwater discharge to springs

Recent research by Lamontagne et al (2021) used environmental tracers to better define the sources of groundwater discharge for individual springs within the Mataranka Thermal Pools (springs) complex. This research identified that there is flow from the CLA both from northern and southern flow systems within the Tindall Limestone aquifer (see Fig. 4) and a component of deeper flow (probably from the Antrim Plateau Volcanics) and shallow, recent recharge, in different springs (see locations in Fig. 10):

> "Major ions, Sr, $^{87}Sr/^{86}Sr$, $\delta^{18}O$-H^2O, δ^2H-H_2O, ^3H, ^{14}C-DIC were consistent with regional groundwater from the Daly and Georgina basins of the CLA as the sources of water sustaining the major springs (Rainbow and Bitter) and one of the minor springs (Warloch Pond). However, 3H = 0.34 TU in another minor spring (Fig Tree) indicated an additional contribution from a young (probably local) source. High concentrations of radiogenic 4He (> 10–7 cm3 STP g–1) at Rainbow Spring, Bitter Spring and in nearby groundwater also indicated an input of deeper, older groundwater. The presence of older groundwater within the CLA demonstrates the need for an appropriate baseline characterisation of the vertical exchange of groundwater in Beetaloo Sub-basin ahead of unconventional gas resource development."

This indicates some level of inter-aquifer connectivity between the CLA and underlying units, either locally (i.e., just at the Mataranka Springs due to local structural geology) and/or regionally. This topic remains a knowledge gap and current research is examining the extent of inter-aquifer connectivity more extensively (Evans et al., 2020).

Locations of groundwater discharge

Most visible groundwater discharge to the Roper River from the CLA occurs into wetlands and spring pools located within Elsey National Park (Fig. 7; Fig. 9), which then flow to the Roper River. Discharge via the main river channel itself also occurs (Karp, 2008); evidence of this includes tufa (calcium carbonate deposits from discharging karst groundwater) along the riverbanks, and major ion chemistry in the springs and river which match CLA groundwater (Karp, 2008). Elsey Creek, which flows into the Roper River from the south, is also sustained by CLA discharge, including from Warloch Pond Spring (Lamontagne et al., 2021). Venting of groundwater discharge to permanent waterholes (e.g. Longreach waterhole) along Elsey Creek has also been identified. Additional tributaries of the upper Roper from the south are also likely sustained by Tindall Limestone groundwater (Fig. 7; Short, 2020).

Springs also provide flow to the Flora River on the western side of the Daly Basin – this is the regional groundwater discharge zone for the CLA northwards out of the Wiso Basin (Fig. 4). Top Springs on the western side of the Wiso basin (See Fig. 5) are also thought to be sustained by discharge from the CLA (Evans et al., 2020). There appear to be less data and less extensive investigation of mechanism of discharge, rates of flow, environmental and cultural values, and vulnerability of these springs, in comparison to Mataranka Springs – a major knowledge gap which should be addressed for the determination of management rules in the Georgina-Wiso WAP.

Groundwater salinity

Water quality in the CLA is variable, with salinities ranging from below 500 mg/L to over 10,000 mg/L. Groundwater is generally considerably fresher in the northern (higher recharge) regions of the CLA and tends to be more saline in the south. Tickell and Bruwer (2017) mapped groundwater salinities for the Georgina Basin and found little correlation with bore/aquifer depth. This indicates that zones of saline water may inter-mingle with or occur close to fresher groundwater, with associated implications for water quality (e.g., creating a risk of salinization if extraction rates in high quality groundwater bores occur close to saline groundwater zones).

Figure 10: Location of Mataranka Thermal Pools within Elsey National Park (Lamontagne et al., 2021).



Ecological and cultural significance of the Roper River, Mataranka Springs & GDEs

The Roper River and Mataranka springs are of high cultural significance for Aboriginal peoples of the region, as documented by Barber and Jackson (2011), Barber and Jackson (2012) and others (e.g., Merlan, 1982). The region is also associated with significant ecological values (Faulks, 2001; Duong and Stokeld, 2021), which are part of the cultural landscape managed under customary law by Traditional Owners:

> "From an Indigenous perspective, the country and the places it contains are active participants in the life of human beings, responding to events and actions in the world, particularly the actions of those people with whom it is strongly connected ancestrally. Therefore an important first step in the proper management of both land and water is appropriate conduct by human beings." (Barber and Jackson 2011).

Barber and Jackson interviewed Aboriginal peoples of the Roper region, and their views help to give a sense of the central and fundamental importance of water in their lives and culture:

> "Water is life, gives life to the land. It feeds the environment, keeps country cool and healthy. We don't like to damage country. Its good for fishing, swimming, camping. We use it for teaching too- cultural stories, bedtime stories, camping beside the river. Its our heritage. We need it to visit, enjoy life. M.H.
>
> If there was no water, all the life would be dead. The animals would be gone if the river dried out. R.S.
>
> Water is needed for the animals and the sacred areas. Water for the country and the people. D.D.
>
> We are dependent on that river. J.R.

> Water is for healing. The water runs out at the crossing. When we get sick, we go and drink the water. M.R
>
> There is a spring close to Beswick community. That water never dies, it will always be there. It gives us water to drink, and for the animals too. J.M."

In the context of early steps in the water planning process, Barber and Jackson (2011) further documented how the Indigenous peoples of the area understand the connectivity between groundwater and surface water, and the importance of upstream flows of these waters for everyone downstream:

> "We are upstream, we are the point of origin. We are guardians for the downstream people and they are the guardians for us. The Elsey mob are getting us involved because we are upstream. They've got the surface water for us, and we've got the underground water for them. The ownership of the two goes hand in hand." A.M.

In line with other accounts of the integral role played by water within living cultural landscapes that connect Aboriginal peoples with their ancestors and other living entities, the cultural significance of water is about more than a collection of 'sacred sites' in a landscape, which may nonetheless play special roles in Indigenous beliefs, ceremonies and Dreaming stories, but cannot describe in full the significance of above and below-ground waters connecting and sustaining the lands collectively termed 'Country' (Ah Chee, 2002; Marshall, 2017; Moggridge, 2020). Nonetheless, the sites discussed below represent important localities featuring in Aboriginal hunting and fishing patterns, stories, songs and ceremonies:

Red Lily Wetlands: Barber and Jackson (2012) document the importance of the Red Lily Lagoons (approximately 20 km downstream of Salt Creek and the eastern extent of Elsey National Park – see Fig. 9), both culturally and economically to the Indigenous peoples of the Roper valley. They documented how the pre-colonial practice of constructing weirs to restrict flows along small tributaries of lagoons was used by Aboriginal people to keep the lagoons filled with water as the dry season progressed, allowing the hunting season to continue for longer and over a more extensive area than could otherwise occur. Eventually this practice was stopped at Red Lilly in the mid-20th Century, as the managers at downstream Roper Station successfully argued in court that it damaged their livelihood by restricting downstream river flows (Barber and Jackson, 2012). Traditional owners continued the practice in other nearby areas (see Barber and Jackson, 2012).

Barlyurra: "Barlyurra is a site complex rather than a specific site. It straddles the Roper River in the vicinity of Red Lily lagoon and upstream. It includes the sites Warrwarrag, Garawi Yirrij, Wa-gardjag, Ngalarrg, Na-Yumbunggan, and Lunjan. The members of the Barlyurra group are affiliated with these sites through the Wijwij, or possum, dreaming. Amy Dirngayg told a story of the possum making a hair belt. There is also a snake dreaming, the detail of which is secret to men and therefore the subject of restricted evidence. Na-Yumbunggan is a ceremony ground for men's ceremony, although Jessie Roberts said that the presence of tourists using the river has caused the cessation of ceremonies on that site. The area is Bangariyn-Ngarrijbalan country, which meets with Gamarra-Burrala country somewhere to the west of Guwarlmbarlg." (Commonwealth of Australia 1990: 107, cited in Barber and Jackson, 2011).

Waterholes & permanent springs: As documented by McGrath (cited in Barber and Jackson 2011), waterholes were a critical part of the Aboriginal economy and a setting for major ceremonies. They were sites of intense conflict during colonization of the northern frontier.

> 'There is a heavy concentration of sites along the Roper River, where permanent water is available. Other sites tend to be associated with permanent waterholes in the

> ephemeral waterways. There is no neat pattern of Dreaming tracks associated with sites. Rather, Dreaming tracks intertwine. (Commonwealth of Australia 1997:113)"
>
> "Much of this country is well watered and well provided with trees. The Mangarrayi pride themselves on their association with the riverine country along the Roper and other bodies of water within their country. (Merlan 1982:146)"

An example of the significance of one such site was documented in Barber and Jackson, 2011:

> "The first site visited by the Dreaming on the claim area is Gorowan, on Salt Creek. The Dreaming then visited Na-Burl (Elsey Falls), Murrwale and Barlmarrag, all on the Roper River. Between Murrwale and Barlmarrag is a waterhole, into which the Garawi jumped and in which it submerged. It travelled underground to the north and re-emerged at Nganawirdbird. This is a place of great significance. It consists of a large sinkhole and limestone cave at the top of a hill. Inside, various limestone features have been painted; they represent the internal organs of the plains kangaroo. The site is on the register of the national estate, pursuant to the Australian Heritage Commission Act 1975. p108."

Barber and Jackson (2011) also document how the ancestral being, known as the Rainbow Serpent, is understood by Aboriginal peoples to populate the Dreaming landscapes of the Roper region - as in many other Indigenous peoples' Dreaming stories Australia wide. The serpent is associated with the underground water flows that connect different parts of the country and keep certain places supplied with permanent water, as told by Bill Harney, Wardaman elder:

> "The spring him fill up with water from the ground, so now him dry [dry season]… that river still runnin' from that spring. Him bin that spring all the time. Important because that Rainbow Serpent they sit down there longa spring every time … When him dry you know that the spring gotta have him water because that Rainbol [regional Aboriginal Kriol term for Rainbow Serpents] there." Cooper and Jackson 2008:27.

The serpent connects the peoples and waters of landscapes that are very distant from the Katherine/Mataranka area, as far as Borroloola on the Gulf of Carpentaria:

> "The story of the Walalu, Stranger Rainbow Serpent is very important and very sacred…The Walalu is sometimes called Yankarra, which is Yanyuwa [language] for "the Stranger", he is called this because he came from such a long way away and, once he moves through Garrwa and Yanyuwa country he keeps moving all the way into Marra country, he moves through Alawa and Mangarrayi country, and finishes his journey at the Mataranka hot springs which is far to the west." (Yanyuwa families et al. 2003).

Water and its aquatic species figure prominently in Indigenous peoples' beliefs and stories (e.g. conception stories) regarding birth, death and connection between ancestral spirits/beings and living people, animals and plants:

> "Birth is important too. The couple bear a child and that child comes out from the spring. The kids come from the water. It's the same story, even when we die. The water is a way that adopted kids come into that country. They get born into there, and they are automatically part of that country. The spirits greet us." M.R and M.H. cited in Barber and Jackson (2011) p19.
>
> "The returning wanggij in some cases is described as incorporeal, but sometimes it may come in the form of an aquatic species, like a fish, since the Mangarrayi believe

> that children emerge from water. Although the wanggij is said to look for its father, it may first be recognized by someone else. (In the instances I was told of, this was always by a close patrilineal relative; one woman caught her brother's child as a barramundi, as is now evidenced by the fact that the hook, which tore its mouth, left a scar that the child bears".

Large (particularly riparian) trees: As outlined in Jackson and Barber (2013), Merlan (1982) recorded how Indigenous peoples of the upper Roper believe that large trees – often located near important water sites – embody individuals from current or recently deceased generations:

> "Trees do have the name. Name of that person. The ones which grow in special places. When we see the Dreaming tree, we know not to touch that. Don't put a fence line through there, put it around it." (R.R.)

This links living Aboriginal people to 'both the lines of descent and to the totemic creatures who created the land' (Jackson and Barber, 2013, p.11).

Ecological values and conservation management

Faulks (2001) conducted an ecological assessment of the Roper River and sub-catchments, and found generally stable riverbeds, limited disturbance of river corridors, creeks, rivers channel, and bank habitats in very good or condition, despite widespread evidence of some disturbance by exotic animals. Exotic vegetation was also found to be widespread. Vegetation found to be dependent on the groundwater flows to the Roper River, its tributaries, and springs (Mataranka Thermal Pools) include communities of *Livistona rigida* (palms) which has restricted distribution in the Top End region and thus considered to be of high ecological significance (Faulks, 2001). These palms require shallow, steady water tables (i.e., < 2 m below surface) before they become stressed and vulnerable to fire. Faulks summarized the findings of earlier surveys of the vegetation of Elsey National Park by Lucas and Manning (1989):

> "The riparian vegetation adjacent to the Roper River within Elsey National Park was described as being diverse, both floristically and structurally. *Pandanus aquaticus*, *Terminalia erythrocarpa*, *Melaleuca* spp., *Eucalyptus camaldulensis* and *Livistona rigida* form dense stands along the river banks. Lush communities of *Livistona rigida* as well as *Ficus platypoda* were associated with springs." (Faulks, 2001).

Knapton (2009) summarised GDEs of the Roper River region, noting the importance of groundwater in sustaining Mataranka Thermal Pools, Red Lily Lagoon, Flying Fox Creek, Mainoru River and Wilton River. In addition to the *Livistona* palm communities, riverbank vegetation, including *Melaleuca argentea* and *Barringtonia acutangular* are thought to almost exclusively utilize groundwater (i.e., they are obligate GDEs). Large *Livistonia* palm and melaleuca communities occur along Elsey Creek and in the vicinity of springs in Elsey National Park and other sections of the Roper River channel. Riparian vegetation communities associated with the permanent water provided by CLA discharge are relatively small in terms of land area, but serve as critically important habitat for animal species – both local and migratory (Woinarski et al., 2000).

Remote-sensing based mapping by Short (2020) further identified distinct regions of groundwater-dependent terrestrial vegetation in Mataranka, using normalized difference moisture and vegetation indices (NDVI/NDMI). Vegetation that persists during dry periods, due to perennial access to groundwater, was identified at permanent water bodies and in areas away from river corridors, which correlated with zones of high (shallow) water tables (Fig. 7).

Stygofauna communities - fauna which live within aquifers, are another type of GDE that widely occur and for which knowledge and data are gradually growing worldwide. A stygofauna survey was conducted in the CLA within the region encompassing the Beetaloo sub-basin and Roper River system, in response to this being identified as a key knowledge gap in the Pepper inquiry. The results are reported by Rees et al., (2020) and Oberprier et al (2021). The surveys identified a diverse range of stygofauna species occurring in the CLA dominated by crustaceans, including the blind shrimp *Parisia unguis*. The widespread occurrence of specific stygofauna across great distances in the CLA is consistent with a high level of connectivity throughout the aquifer system (as opposed to stygofauna which exhibit a greater level of short-range endemism, which indicate localized evolution and habitat conditions). Identified species showed relatively little correspondence with stygofauna communities documented in other regions such as Western Australia, where stygofauna surveys have covered a larger and relatively diverse range of settings (Rees et al., 2020).

2. Risks to groundwater dependent ecosystems and associated values from current allocation rules (storage-based estimates of sustainable yield)

The predominant risks associated with an increase in groundwater extraction rates from the CLA are:

i. Reduced flows of groundwater to the Roper River, Mataranka Thermal Pools and other streams, springs and wetlands of the region. If these groundwater discharge flows and/or CLA groundwater levels were to decline below key thresholds, complete loss of springs and baseflow to rivers may occur. This would lead to the loss of vegetation communities and animal habitat, and incalculable loss and damage to the cultural values associated with both specific sites (e.g., springs, waterholes, and wetlands) and the health of 'country' and Aboriginal culture from a holistic point of view (see section 1c). Stygofauna may also lose their habitat if extensive drawdown occurs in regions of the aquifer they inhabit.

ii. Interference to existing water users and water supplies in the region. For example, a significant drop in groundwater elevations in the CLA may lead existing extraction bores used for stock/pastoral water supply to lose pressure or (in extreme cases) run dry. This is particularly significant in the Daly Basin, where there are already quite a number of pastoral bores utilising CLA groundwater. Significant loss of dry season river flows in the upper Roper River would lead to a reduction in downstream river flows, affecting downstream surface water users. In dry periods, this could (for example) result in saltwater ingress affecting the Ngukurr Aboriginal Community (Jolly et al., 2004; Zaar, 2009). Non-consumptive uses of water (e.g. tourism, fishing and hunting) may also be impacted, with flow-on economic effects and impacts on Indigenous customary uses.

Depletion of significant volumes of storage within an aquifer are also associated with other irreversible negative consequences such as:

- land subsidence and compaction of the aquifer matrix: In limestone terrains this can lead to collapse structures (e.g. sinkholes) at the surface. Aquifer compaction can also impact on aquifer properties, e.g., reducing transmissivity and future groundwater storage capacity (Ojha et al., 2018). This typically affects unconsolidated sediments but has also been documented to impact carbonate aquifers of similar type to the CLA (Laroque et al., 1998).

- Degradation of water quality, through drawing in poorer quality water from layers adjacent, above or below the CLA. It is known that the salinity of groundwater can be variable in different parts of the CLA – for example with TDS concentrations exceeding 10,000 mg/L in parts of the Georgina Basin (Tickell and Bruwer, 2017), but there is currently limited assessment of risks of migration of saline water bodies into fresher parts of the aquifer system under the influence of groundwater extraction.

The rest of this section reviews current water policies in the Northern Territory and assesses the extent to which the above consequences are likely to occur under these policy settings if there is a significant increase in demand for groundwater from industries such as irrigated agriculture and shale gas. Section 3 outlines management approaches that can ensure protection of the groundwater dependent values and avoid these negative consequences.

The Northern Territory Water Allocation Planning Framework

Under the Northern Territory Water Act, water licensing is conducted based on rules set out in Water Allocation Plans for each region. However, large areas of the NT, including the area encompassing most of the CLA and Beetaloo Sub-basin, do not yet have declared water

allocation plans. Only 28% of licenses in the NT occur within areas with a declared WAP (O'Donnell et al., 2022). In accordance with recommendation 7.7 of the Pepper Inquiry, it is understood that the NT Government is currently working on Water Allocation Plans that will encompass the CLA's major sub-zones (Mataranka, Flora Tindall, Georgina Wiso), with the goal of releasing these in 2022-23. Currently, the only publicly available WAP draft is the Georgina-Wiso plan (Northern Territory Government, 2022a).

In the absence of a water allocation plan, the current policy governing groundwater licensing is the Northern Territory Water Allocation Planning Framework, which defines two separate zones of the Territory - Top End and Arid Zone. Within these two zones, different rules apply governing the amount of groundwater that can be extracted from a given aquifer.

In the Top End Zone:

> At least 80 per cent of annual recharge is allocated as water for environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to 20 per cent of annual recharge.

In The Arid Zone:

> There will be no deleterious change in groundwater discharges to dependent ecosystems, and total extraction over a period of at least 100 years will not exceed 80 per cent of the total aquifer storage at start of extraction.

These rules are the basis for calculating an "estimated sustainable yield" (ESY) in a given region. Surface water extractions are also subject to different rules within the two zones.

It is unclear what rules will be adopted in the different water allocation plans currently in development. For example, it is unclear how an ESY (overall cap on licensed extractions for a given region) will be determined, and what additional groundwater management rules (e.g., mechanisms such as trigger levels to protect groundwater dependent ecosystems) will apply within the water allocation plan areas. From available minutes on the public record, and statements by the NT government, it appears that the Top End, Arid Zone or other rules that calculate ESYs based on a percentage of aquifer storage, may be used as a basis for developing the plans. For example, minutes of the Mataranka Tindall Water Advisory Committee[3] indicate that it has been proposed that the Arid Zone rules be applied to the Tindall Limestone near Larrimah, despite this region being north of the Top End/Arid Zone boundary (i.e., within the Top End zone).

The draft Georgina-Wiso WAP appears to have adopted an approach that bases the ESY on a fraction of the average groundwater recharge (similar to the Top End rule), however the fraction of recharge is substantially higher than for the Top End rule, and there are considerable issues which call the methodology used to develop the proposed ESY into question (see the section on Recharge above, and further discussion below in section 3).

The Top End/Arid Zone delineation

Figure 10 shows the current boundary between the Top End and Arid Zones, based on a technical report completed by the NT Water Resources Division in 2020[4]. The line essentially relies upon surface water catchment boundaries – with northward flowing catchments forming the Top End, and inland-flowing catchments forming the Arid Zone. The report reviews additional climate and hydrological datasets (e.g., soil moisture, evapotranspiration,

[3] https://depws.nt.gov.au/__data/assets/pdf_file/0008/1049453/mataranka-tindall-wac-meeting-11-minutes-and-appendices.pdf

[4] Classification of the Top End and Arid Zone for Northern Territory water resources. Water Resources Division Technical Report 55/2020.

runoff, deep drainage), which also broadly correspond with a transition in climate and hydrological conditions across the line (e.g., the 600 mm/year mean rainfall contour). However, this average rainfall contour does not align with an accepted definition of arid, which generally defines arid zones as having less than 250 mm rainfall per year (Holzapfel, 2008). This applies only to the south of Tennant Creek in the NT. It is also noted in the report, that the boundary line does not represent a distinct or meaningful boundary with respect to the aquifers and groundwater flow systems of the Northern Territory:

> "It is acknowledged that aquifer boundaries rarely align with surface water catchments. However, it is not practical to determine a boundary based on aquifers when there can be a large degree of uncertainty in where a boundary might be defined. Aquifer boundaries, where they have been mapped, may be subject to change by tens to hundreds of kilometres with improved information. By contrast, surface water catchment boundaries are easily defined and readily derived from high-quality (high spatial resolution) national scale elevation data. Once defined, surface water catchment boundaries are not likely to change in the future and are a much better basis upon which to set a boundary such as the Top End/Arid Zone boundary."

Based on the line delineated in the Technical Report (Fig. 11, Fig. 12), the entire Daly Basin, encompassing the Tindall Limestone, and northern Wiso and Georgina basins are within the Top End zone. Figure 12 shows draft boundaries for different water allocation plan districts. The Flora Tindall, Mataranka and northern Georgina Wiso WAP areas are within the Top End zone, while the southern Georgina Wiso WAP area (encompassing most of this WAP area) sit within the Arid Zone. Noting that (as outlined in section 1b), recharge to the Tindall Limestone within the boundaries of the Daly Basin is substantial and appears to exceed throughflow from the Georgina Basin, it is doubtful that the use of Arid Zone rules anywhere within the Daly Basin accords with the notion that the CLA is a 'low recharge high storage' aquifer (see Table 3 and Fig. 4). Hence, even if the Arid Zone rules were to be considered an appropriate management regime for such aquifers (this topic is addressed further below), their use within the Daly Basin would be questionable.

Basis of the Top End/Arid Zone rules

Limited information was identified to explain the original rationale for dividing the Northern Territory into the two zones for the purposes of water management. However, testimony to the Australian Senate in 2003 by the former NT Water Controller, Mr Ian Smith, gives an indication of the basis:

> "The simplest way to explain the allocation framework [as it applies in the Top End zone] is that we seek to retain at least 80 per cent of river flows and 80 per cent of the ground water resource for environmental use. Thereby, in a planning sense and in our licensing procedures, we are looking to license up no more than 20 per cent of the available river flow anywhere in a catchment and, essentially, no more than 20 per cent of the ground water recharge. In a ground water balance sense and in a regional sense, that means that we are retaining at least 80 per cent of the discharge to the environment from ground water systems."

With respect to the Arid Zone rules Mr Smith commented:

> "The behaviour of our aquifers is different in the south than in the north. Our recharge mechanisms are fundamentally different and are much lower, but we have much larger storage. Our policy for aquifers in the southern two-thirds is to

permit mining of the resource over at least 100 years, but our mining at this stage is limited to 80 per cent of the aquifer storage at the start of extraction.[5]"

The rationale for allowing up to 80% of storage to be depleted from aquifers in the Arid Zone may derive partly or in whole from an understanding of the water needs of the township of Alice Springs - where groundwater supplies domestic water to one of inland Australia's largest communities. Groundwater recharge to the aquifer supplying Alice Springs is very limited (estimated to be approximately 750 ML/year) and current allocations (approximately 11,000 ML/year) far exceed this recharge, resulting in long-term depletion of storage in the aquifer (DLRM, 2016). The Arid Zone contingent rules allow this over-draft of the aquifer, in the interests of sustaining water for the township's essential needs. The application of the same rules elsewhere in the NT needs to carefully consider this context – i.e., overdraft of groundwater to supply essential water to a major township is different to applications to extract water at unsustainable rates for economic development. The current WAP still limits depletion of storage in the Amadeus Basin to 25% (not 80%) over 100 years (DLRM, 2016).

[5] Rural and Regional Affairs and Transport References Committee Senate transcript 18/11/2003: https://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id:committees/commsen/7147/0004



Figure 11: The Top End and Arid Zone boundary, as defined in the Northern Territory Water Allocation Planning Framework, also showing Beetaloo sub-basin and SREBA study area. Red and black lines show approximate locations for Fig. 15. Image credit: First Class Communications.

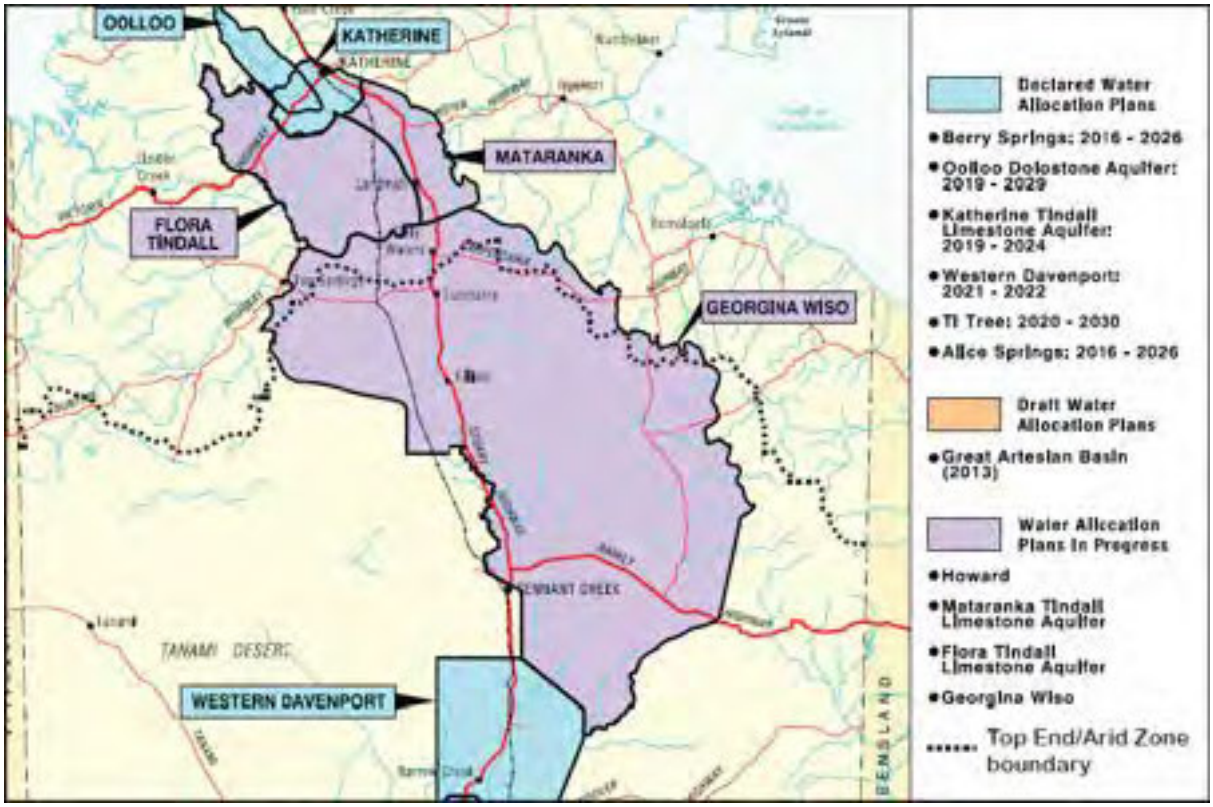


Figure 12: Map of water allocation plan districts where water allocation plans are currently being developed (as of October 2022), with current Arid Zone/Top End boundary marked.

Recent expert opinion on the Top End/Arid Zone rules

The Pepper inquiry reviewed the NT Water Allocation Planning Framework and found that the use of the Arid Zone contingent rules (for onshore gas or any other extractive use) would: '..essentially permit 'mining' of the groundwater resources and would be ecologically unsustainable'. Recommendation 7.7 of the inquiry stated that Water Allocation Plans should be developed for the northern and southern Beetaloo sub-basin with the following principles:

- The new northern Sub-Basin water allocation plan provides for a water allocation rule that restricts the consumptive use to less than that which can be sustainably extracted without having adverse impacts on other users and the environment; and
- The southern Sub-Basin water allocation plan prohibits water extraction for any onshore shale gas production until the nature and extent of the groundwater resource and recharge rates in that area are quantified.

In a recent groundwater licence application near Larrimah that was initially granted to the Northern Territory Land Corporation, but then withdrawn, the Water Resources Review Panel concluded that the use of different allocation rules in the northern and southern parts of the CLA (which, as outlined in Section 1, are to some degree hydraulically connected), is problematic:

> "The application of a significantly different allocation criteria of 20% of storage available for consumptive use (Top End Zone) to 80% of storage available for consumptive use (Arid Zone) to different portions of an aquifer system with high geologic and hydraulic connectivity is not consistent with proper groundwater management. It is not logical to have significantly different allocation criteria in neighbouring management areas for a hydraulically and geologically continuous aquifer, especially if it important to maintain throughflow and natural discharge to the Roper River."

The panel also agreed with the opinion expressed by the Director of Water Planning and Engagement at the time that:

> "Drawing down storage by 80% as proposed by the contingent allocations in the NT WAP Framework will not provide for the environmental and cultural water requirements supported by the aquifer. The lowering of the height of the upper surface of the aquifer after 100 years of extraction has the potential to reverse the hydraulic gradient removing through flow to areas near the southern side of the Roper River and cause water to flow in the opposite direction towards Larrimah.[6]"

These opinions accord with the most up-to-date literature and science on the topics of aquifer responses to groundwater extraction, prevention of aquifer depletion, protection of GDEs, and sustainable groundwater management approaches to achieve these aims (Alley et al., 2002; Ponce, 2007; Gleeson et al., 2012; Doody et al., 2019; Bierkens & Wada, 2019; Walker et al., 2021). These topics are discussed further below.

Problems with the use of a percentage of storage as a basis for sustainable yield

The concept of a Sustainable Yield in the management of groundwater resources has developed over the past hundred or more years. This has occurred in line with evolving views on sustainable water and other resource management, increasing understanding of the interconnections between groundwater and other parts of the water cycle, and awareness of the ecological and cultural values sustained by groundwater flows.

Early concepts regarding the sustainability of groundwater usage began with the 'Safe Yield', which corresponded with the idea that if groundwater extraction did not exceed annual recharge to an aquifer, the aquifer would be protected against long-term storage depletion, thereby allowing ongoing access to the resource into the future (Lee, 1915; Todd, 1959).

It was subsequently shown that this was an overly simplistic way to define 'safe' or 'sustainable' groundwater yield, most importantly because it does not account for the critical role played by groundwater discharge in maintaining surface flows to streams, springs, and connected ecosystems (Theis, 1940, Alley et al., 1999, Seward, 2006), and the ways that these flows, as well as recharge itself, may be changed significantly by groundwater pumping. Groundwater is simply one part of the water cycle, during which it is stored for a period in an aquifer, on its way between infiltrating the land surface (as percolating rainfall) and reaching the oceans or atmosphere via discharge to streams, submarine groundwater or evapotranspiration. As such, extracting the annual recharge flowing into an aquifer deprives the downstream environment (within and/or external to the aquifer), of these flows, which may cause unacceptable environmental, social, cultural and/or economic impacts.

C.V. Theis's seminal work "On the source of water derived from wells" (1940), demonstrated how aquifers and their connected surface waters respond to groundwater extraction in a combination of three ways:

1. The amount of water in storage within the aquifer is reduced (storage depletion)
2. Additional recharge will be drawn into the aquifer from the surface (if it is available in the form of excess or 'rejected recharge')
3. The amount of groundwater discharge to the surface (e.g., baseflow to streams and flow to springs and wetlands) will be reduced

Alley et al (1999) summarised these changes pictorially (reproduced as Fig. 13 below). The second and third changes to the pre-existing water balance are collectively termed 'Capture' by most hydrologists (following Theis). This reflects the fact that this water, which would

[6] Water Resources Review Panel, *Re: Controller's Decision to Grant Groundwater Extraction Licence TLAM10002*, 17 May 2021.

otherwise be available as flows to the surface at some point in time, is re-directed to the pumping wells, meaning the surface is ultimately deprived of it (Theis, 1940).

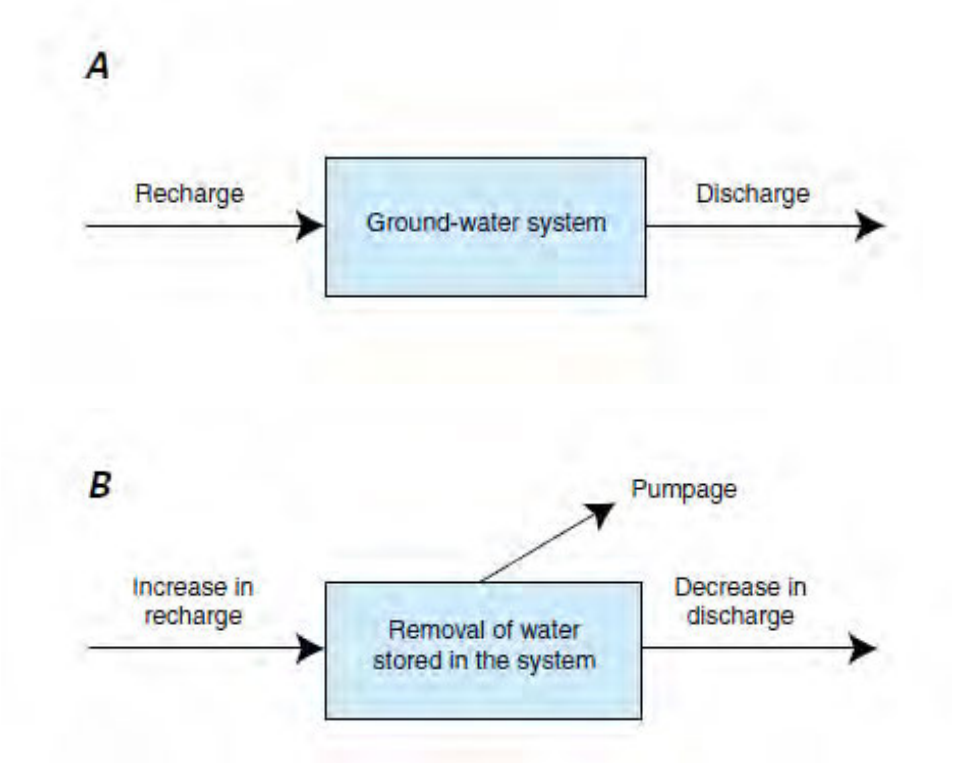


Figure 13: Conceptual diagram representing the three changes which occur (in some combination) when extraction of groundwater disturbs an existing water balance. From Alley et al., (1999).

It has become widely accepted (and demonstrated in modelling studies) that in the long-term, the majority of groundwater extraction is balanced by Capture – i.e., pumping a particular volume over time will result in an equivalent reduction in water discharging from the aquifer. For example, modelling by Konikow and Leake (2014) showed that in the United States, much of the water extracted within major groundwater pumping districts ultimately reduces baseflows to streams. As such, establishing the importance of these baseflows and acceptable levels of impact to these, should be a top priority for sustainable groundwater management.

As pointed out by Theis (1940), depletion of storage is generally an important response of an aquifer to pumping in the early phases of extraction; however, in the long term, Capture will inevitably become the dominant source of water to wells, as the inter-connected groundwater-surface water system approaches a new equilibrium water balance. While in many cases the timescale to reach this point of equilibrium is very long (e.g., Bredehoeft and Durbin, 2009), and in the interim, significant fractions of the pumped water may be derived from storage depletion, the setting of sustainable yield volumes should ultimately focus on determining where the loss(es) of groundwater discharge will occur (and any additional recharge drawn into the aquifer from the surface), and how important these waters are from environmental, economic, and socio-cultural perspectives (Alley et al., 1999, Seward, 2006; Ponce, 2007; Pierce et al., 2013). Direct impacts of storage depletion (e.g., drawdown to the point that GDEs can no longer access groundwater) must also be considered.

The determination of recharge rates is still an important pre-requisite for assessing sustainable groundwater extraction; setting sustainable yields as a fraction of recharge is a way to ensure ongoing access to groundwater into the future, and allows analysis of whether extraction at different rates can be considered ‘renewable’ or ‘non-renewable’ (Bierkens and Wada, 2019). This is in line with current thinking about the sustainable use of natural resources, according to the principle of inter-generational equity (World Commission on

Environment and Development, 1987). Further, recharge is often similar to natural discharge from an aquifer. Thus, setting extraction rates as a fraction of recharge in an aquifer or groundwater 'catchment' will generally limit (but not entirely prevent) reductions in groundwater discharge to springs and streams from that aquifer. However, at least equal or arguably greater focus should be on determining the rates of discharge of groundwater to groundwater dependent streams, springs, wetlands, vegetation and fauna, and the extent to which water sustaining these will be intercepted or reduced by pumping at a given extraction rate. This must be reflected both in the policy rules for setting sustainable yields, and in the focus of scientific work undertaken to define what this should be for a given aquifer/region.

The NT contingent water allocation rules and sustainable yields

The Arid Zone contingent rule (with respect to groundwater) encompass two components:

a) No deleterious effect on GDEs
b) Aquifer storage can be 'depleted' by up to 80% of initial storage volume on a 100-year timeframe

These two parts of the rule may seem to be distinct criteria for assessing the sustainability of groundwater extraction; however, they are strongly inter-dependent and, in systems which receive limited recharge (where the rule is applied), contradictory. In settings where recharge is small relative to storage, extracting 80% of the storage volume will inevitably result in the loss of groundwater flows to connected surface water systems and other GDEs. GDE health depends upon the maintenance of aquifer water levels above thresholds which allow groundwater discharge to springs and baseflow to rivers, ET by vegetation, and to support stygofauna inhabiting the subterranean space of the aquifer. Maintaining GDEs also depends upon the maintenance of flux rates to surface discharge points. This is *related* to maintenance of aquifer water levels, but often in a non-linear way (as illustrated in Fig. 14):

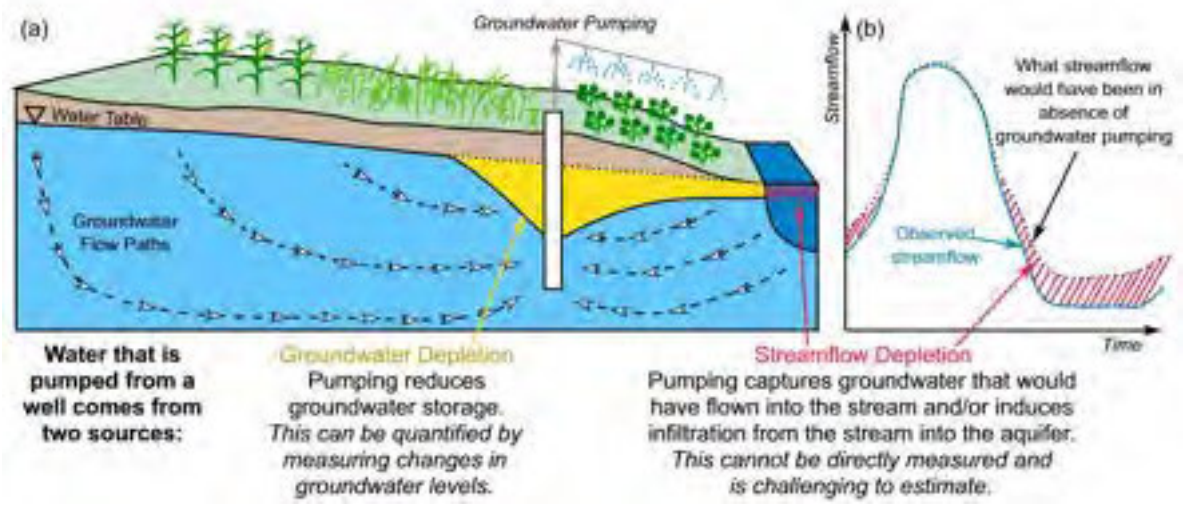


Figure 14 - Example showing how groundwater extraction causes a combination of groundwater storage depletion, and reduction in flows from the aquifer to streams or other surface GDEs, through 'Capture'. From Zipper et al. (2022).

As discussed above, in the long term, most groundwater extraction is balanced by a reduction in the amount of groundwater discharge to the surface or near surface (i.e., GDEs). This may be facilitated by a reduction in throughflow rates between adjacent aquifers (as would apply in the case in the CLA across the Georgina/Daly and Wiso/Daly boundaries) as well as through reduction in flux rates near the GDE(s). If a GDE is fully dependent on groundwater, and there aren't other available sources of 'Capture' to balance extraction, the reduction in flux may result in a 1:1 reduction in water availability to the ecosystem (Hatton and Evans, 1998).

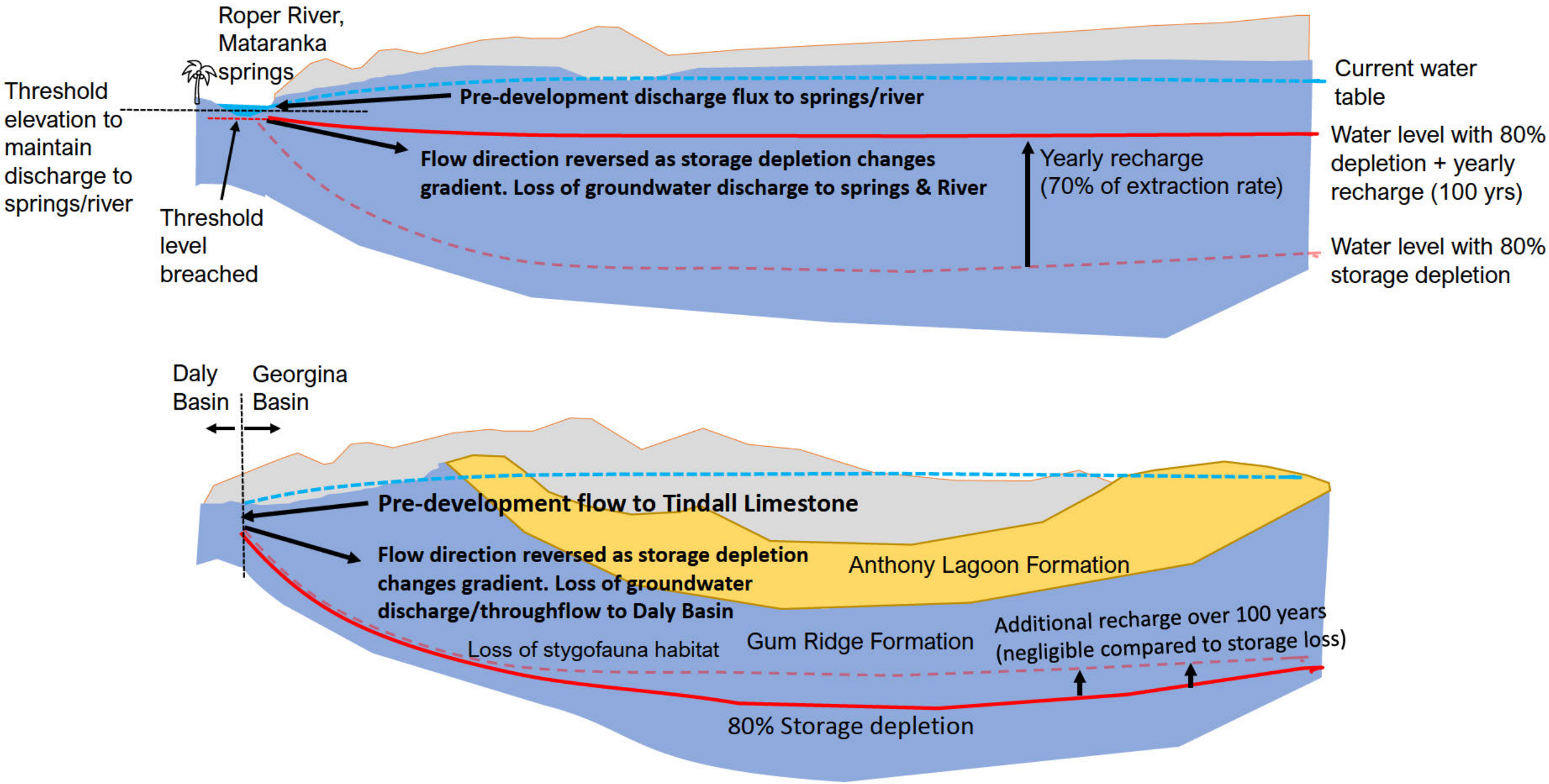
The depletion of water in storage that occurs during the early phases of groundwater extraction - which, in large aquifer systems with long response times, may continue for hundreds or thousands of years, will inevitably cause changes to groundwater levels and flow gradients. |GDEs may be lost entirely as a result of these changes. This can occur by one or both of the following:

a) The groundwater levels at the point of discharge reduce below a threshold elevation (usually the land surface height or root zone depth), which causes groundwater flows to the (near) surface at this point to cease, thereby depriving the GDE of water completely (Figure 15)

b) The groundwater flow gradients change in direction, to the point that groundwater from the aquifer in question no longer flows in the direction of the GDE, and flux from the aquifer to the GDE ceases (again, depriving it of water) – Fig. 14 & 15. This mechanism can cause the loss of springs and baseflow without causing any significant drop in the groundwater *levels* at the point of discharge (e.g., Currell, 2016; Fig. 15). This is why GDE management programs dependent on maintaining water levels only, without also considering effects of pumping on hydraulic gradients and flow rates towards the ecosystem (and setting a cap on rates of extraction accordingly), may be ineffective at protecting GDEs (Noorduijn et al., 2019). Note that throughflow between basins - such as the flows from the Georgina Basin into the Daly Basin, which replenish groundwater along its southern boundary, would be reduced by such changes to groundwater flow gradients (Fig. 15b).

The depletion of even a small amount of the water in storage in an aquifer will change groundwater levels and flow gradients and risk either or both of a) and b). In a case where 80% of the storage volume is depleted, and the recharge rate is small relative to overall storage, it is almost certain that both will occur, as shown conceptually in Figure 15.

Regarding the proposed estimated sustainable yield in the draft Georgina-Wiso WAP (calculated as 40% of recharge, averaged over a 50-year period): As discussed in section 1b, it is likely that in most years this extraction rate would far exceed recharge (as recharge is rare and episodic), and that this situation may persist for many consecutive years or decades. In this scenario, a significant level of storage depletion is likely to occur in between major recharge events. The flow-on effects of such periods of storage depletion – e.g. on throughflows to the Tindall Limestone, groundwater quality, or GDEs (which are to date poorly characterized , remain unknown.


Roper River, Mataranka springs
Threshold elevation to maintain discharge to springs/river
Threshold level breached
Pre-development discharge flux to springs/river
Flow direction reversed as storage depletion changes gradient. Loss of groundwater discharge to springs & River
Yearly recharge (70% of extraction rate)
Current water table
Water level with 80% depletion + yearly recharge (100 yrs)
Water level with 80% storage depletion
Daly Basin
Georgina Basin
Pre-development flow to Tindall Limestone
Flow direction reversed as storage depletion changes gradient. Loss of groundwater discharge/throughflow to Daly Basin
Anthony Lagoon Formation
Loss of stygofauna habitat
Gum Ridge Formation
Additional recharge over 100 years (negligible compared to storage loss)
80% Storage depletion

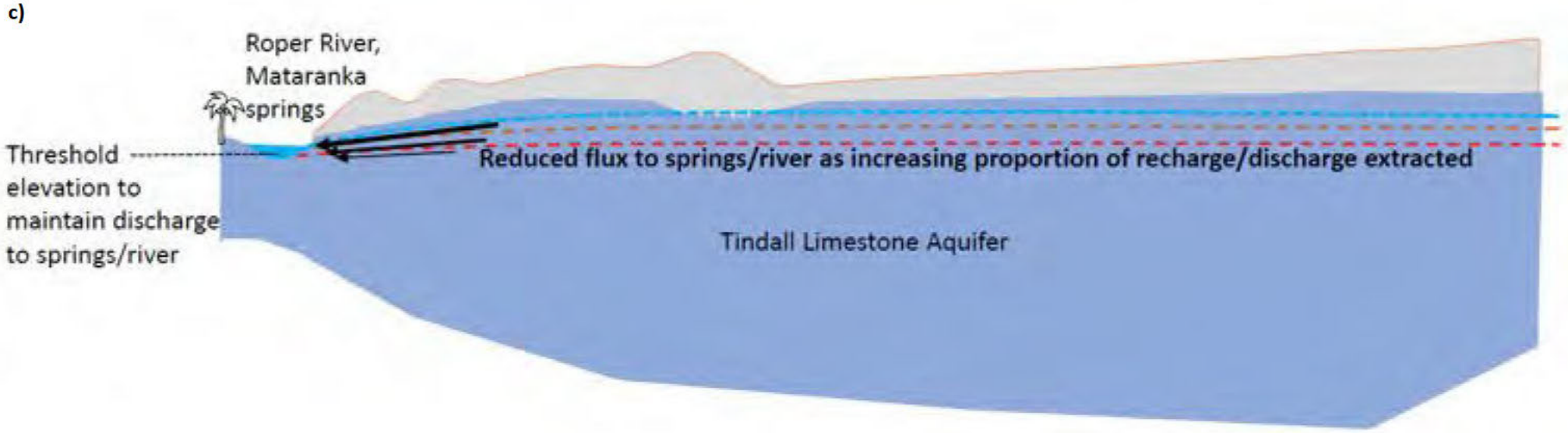


Figure 15: Conceptual diagrams showing how depletion of storage causes consequences for groundwater dependent ecosystems, surface water and inter-aquifer flows. Extraction of any significant proportion of storage will reduce rates of groundwater discharge to the surface and/or adjacent aquifers. Depending on the ratio of recharge to total storage, and extent to which discharge flows are captured by pumping at different locations and rates, these flows may be entirely lost. Example (a) conceptually represents the Tindall Limestone aquifer with 80% of estimated storage (28,200 to 56,400 GL) extracted over 100 years, with recharge of 330 GL/year (after Bruwer and Tickell, 2015). The red line represents the approximate water level, incorporating extraction offset by yearly recharge. Flow to the Roper River and springs is lost, due to change in groundwater flow directions and the capture of discharge. (B) Potential effect of depleting 80% of storage in the Georgina Basin. Due to minimal recharge, storage depletion would reverse hydraulic gradients. Throughflow into the Tindall Limestone (Daly Basin) would become a net loss of water to the Georgina Basin (Gum Ridge Formation), which is likely to reduce flows to GDEs in the Daly basin. (C) shows how extraction of any significant proportion of recharge and/or discharge from the Tindall Limestone would reduce flux rates to GDEs (e.g., the Roper River and Mataranka Springs), without necessarily reversing the flow direction or breaching water level thresholds required to sustain these sites. Locations of a) and c) correspond approximately to north Larrimah to Mataranka (red line on Fig. 11); b) approximately from the CLA west of Tennant Creek to Daly Waters (Black line, Fig. 11). Figures not to scale. More precise field data & modelling are required to predict the spatial and temporal consequences of groundwater extraction at different rates in different regions accurately.

A comparison of volumes of extraction that could be permissible under the Arid Zone rules to annual recharge rate (as per the data in Tables 2 and 3) indicates that in the Georgina basin, permissible extraction over a 100-year period would represent between approximately 60 to 400 times the volume of recharge expected over this timeframe. In the Daly Basin (where storage capacity is estimated to be lower and recharge rate higher), extraction volumes would approximately correspond with (or exceed) the estimated rate of recharge over 100 years, which is likely to substantially reduce flows to GDEs (Fig. 15).

Consideration of climate change impacts on recharge and aquifer storage

Much of the recharge in CLA emanates from annual rainfall. As with other regions, groundwater across the CLA will continue to respond to the impacts of climate change through changes in the characteristics of rainfall (e.g., intensity, seasonality). The negative trends in annual recharge between 2003 and 2016 in some critical areas of the CLA (Fig 4b) highlights this further, suggesting that slight changes in the intensity of annual rainfall and/or increased evapotranspiration rates could create a water budget deficit, affecting rainfall-based storage contributions to the aquifer. Recharge may be significantly less in some years compared to long term averages – the limited analysis of hydrographs conducted for the Georgina basin indicates that this is particularly true in this basin, where substantial recharge appears to have only occurred once in a few decades. Groundwater extraction at rates that exceed recharge even temporarily (due to its episodic nature) could coalesce with prolonged droughts, to deplete storage faster than expected, lowering the water table and ultimately damaging GDEs and their unique biodiversity. Damaging impacts of severe dry conditions on hydraulic properties (e.g., transmissivity of karst aquifers in France), which may not be readily reversible, have been documented elsewhere (Green et al. 2011).

Threats to environmental and cultural values sustained by groundwater if groundwater extraction rates representing a substantial fraction of storage and/or recharge are permitted

As outlined above, the use of Arid Zone contingent rules or other storage-based method to calculate sustainable yield for groundwater extraction from the CLA would pose a high risk of damaging sites dependent on groundwater discharge from the aquifer. Extracting up to 80% (as permitted under the current contingent rule) or 40%, as suggested by APPEA (2020) would pose a very high risk of damaging sites and values dependent on groundwater from the CLA e.g., through reversing hydraulic gradients away from GDEs, breaching key groundwater level thresholds for these, and/or compromising throughflows between different regions. Extraction of substantially lower proportions of storage would still pose significant risks to GDEs, through capture of flows to the surface and/or root zone (see section 2).

The extraction of a large fraction of recharge - e.g., 40% of the estimated average recharge, as proposed in the current draft Georgina-Wiso Water Allocation Plan, may similarly pose risks to multiple values sustained by CLA groundwater. Important considerations regarding the proposed adoption of an estimated sustainable yield of approximately 260 GL/year in this plan (as per the current draft) include:

1. Estimates of recharge rates within the Georgina and Wiso basins remain uncertain, with conflicting values derived from different methods (e.g., Table 1 of the Draft WAP Background report – Northern Territory Government, 2022b). The model-derived estimates of recharge used to calculate the 40% fraction of recharge are almost double the previous recharge estimate using the same model. From review of the reporting it appears that the major difference is a shortening of the period used to model recharge compared to the previous model run (Knapton, 2020). This means that the volume currently estimated to be 40% of average recharge, may not actually represent this fraction of the true recharge. Under the previous modelling (Knapton,

2020), the proposed ESY would represent more than 75% of long-term averaged recharge to the Georgina Basin. If the use of a fraction of recharge is the approach preferred for calculation of an ESY in this region, then using the current minimum estimated recharge rate (and taking a fraction of this) would be a more conservative approach, given the current lack of data. Sound justification for the use of 40% of the recharge should also be provided.

2. Recharge to the CLA is thought to be very infrequent in the region covered by the draft WAP (Georgina and Wiso basins). As discussed in Tickell and Bruwer (2017), it is likely there have only been a small number (three or four) of unusually wet climatic periods since monitoring began in the early 1900s, in which effective recharge to the Georgina Basin CLA has taken place. Extracting a substantial proportion of the long-term averaged recharge each year would therefore mean extraction would far exceed recharge in most years, excluding these episodic recharge events (in which recharge would far exceed extraction). If there are many years or decades between substantial recharge events - as occurred for nearly four decades between the 1970s and early 2010s, the level of yearly extraction proposed along with limited recharge would result in effective mining of aquifer storage between recharge events, causing substantial reductions in groundwater levels (drawdown) and fluxes during these periods. Better understanding of the importance of maintaining groundwater levels for protecting stygofauna communities (e.g. Rees et al., 2021), throughflows to other parts of the CLA (Evans et al., 2020), water quality (Tickell and Bruwer, 2017) and ensuring structural integrity of the aquifer are required before such extraction rates - and the groundwater level reductions they would cause - can be said to be sustainable, i.e., protective of environmental, cultural and economic values.

3. Groundwater discharge mechanisms from the Wiso and Georgina basins are poorly understood. It is questionable to believe that there is little or no groundwater discharge from these basins currently occurring – as appears to be assumed in the draft WAP (e.g., Table 1 of Northern Territory Government, 2022a). Outflow of groundwater is likely to be occurring at rates of similar order to the estimated long-term average recharge – in line with general steady-state conditions typically encountered in relatively un-developed aquifers (Alley et al, 1999). The outflow/discharge of groundwater is likely to be occurring either through evapotranspiration, flow to springs (such as those on the west of the Wiso basin that are currently poorly understood), groundwater throughflow to other regions (which has been considered but may be under-estimated), and/or inter-aquifer leakage. The large imbalance between estimated recharge and outflow/discharge currently reflected in the draft WAP may well reflect limited data currently available to quantify groundwater outflows rather than an actual large imbalance between inflows and outflows.

Ultimately, the extraction of the volumes of water proposed each year in the draft Georgina Wiso WAP would likely have flow-on effects for the rest of the CLA water balance and associated values. As discussed in section 3, 40% of the long-term average annual recharge is at the high end of typical fractions of recharge used to calculate estimated sustainable yields in other jurisdictions, such as the SDLs determined for Murray Darling Basin catchments (Walker et al., 2020). Without addressing the issues described above, the adoption of the proposed ESY/extraction rates in the draft WAP may seriously jeopardise environmental and cultural values. Of further considerable concern is the fact that cultural and environmental values supported by the CLA groundwater in this region (encompassing appropriate stakeholder engagement) appear not to have been effectively documented and considered in the setting of the ESY, and this is not proposed to be addressed until halfway

through the life of the plan. This runs counter to best practice water management approaches, which ensure that stakeholder management occurs early and frequently in the determination of water plan rules (e.g., Thomann et al., 2020 and further discussion in Section 3).

In the Daly Basin, the sites most at risk from excessive extraction of CLA groundwater would be the Roper River and Mataranka Springs (on the east), and to the west, Flora River and its associated springs. It is well established that these sites are strongly dependent on groundwater discharge from the Tindall Limestone aquifer. If extraction rates within the Daly Basin (e.g. Flora Tindall and Mataranka WAP areas) allow for a significant percentage of storage depletion, then these sites would be at high risk of harm. Even if significant extraction rates are permitted a long distance from the GDEs (e.g. groundwater extractions focused near Larrimah, or Daly Waters, above the Beetaloo sub-basin), the most likely *long-term* consequence of increasing groundwater extraction rates within the Daly basin is the capture of discharge that ultimately sustains these critically important GDEs (Ponce, 2007). Further, the depletion of storage in the Georgina and/or Wiso basins to the south would result in throughflow from these basins no longer sustaining the Tindall Limestone, and (as shown in Fig. 15b) a change to a net loss of groundwater throughflow, with groundwater from the Tindall Limestone instead flowing back towards the Gum Ridge Formation.

Ecohydrological and modelling studies have yet to (as far as we are aware) determine the threshold groundwater elevations required to sustain the Mataranka springs, Roper River and other springs and groundwater dependent streams and vegetation above the CLA, nor have they determined the extent of reduction in baseflow and/or associated environmental impacts that would likely be caused at different extraction rates in different areas. Some estimates using numerical modelling, examining potential impacts of extraction at different rates on baseflow to the Roper River have been documented; for example, Bruwer and Tickell (2015) modelled the effect of extracting 20% of estimated recharge of the Tindall Limestone via a wellfield near Larrimah, finding that this would result in a reduction in baseflow to the Roper River of approximately 20% in the long-term. The environmental consequences of such a reduction (i.e., extent to which the values described in section 1c would be harmed) are not known, although they have been explored in Jolly et al. (2004) to some extent. Reductions in flow to springs and/or baseflows in the Roper would cause corresponding declines in river flows downstream. Thus, as well as groundwater dependence of Mataranka Springs and Roper River from the CLA in its upstream sections, downstream sections of the Roper are vulnerable to saltwater intrusion if flows decline below certain thresholds. In the 1950s and 60s, substantial reductions in flow along the Roper caused the loss of the water supply for the Ngukurr Aboriginal community (Zaar, 2009).

It is currently unclear what the major groundwater discharge mechanisms for the Georgina and Wiso basins are; throughflow to the Daly Basin is clearly one component, and discharge to springs a probable additional component (Evans et al., 2020), but it is not clear where or how much discharge takes place, or what the ultimate fate of much of the CLA groundwater flowing through these basins is. This may encompass cross-flow to other aquifer units and/or diffuse evapotranspiration (including by GDEs that are not well documented). As such, the consequences of pumping at rates that deplete storage, and thus reduce groundwater discharge significantly, are not well understood. Stygofauna communities identified in the CLA by Rees et al., (2020) would be at high risk of losing their habitat if a significant proportion of storage was depleted in these basins, due to the low recharge rates - which would mean extensive drawdown would occur over wide areas, with limited recovery of water levels for a long period of time. Irreversible aquifer compaction, development of surface collapse structures and/or reductions in groundwater quality (e.g. increasing salinity due to enhanced leakage from low-quality water bodies) also cannot be ruled out.

3. Advise on how an "estimated sustainable yield" should be calculated for the purposes of water allocation plans in the Beetaloo Basin to safeguard against risks to dependencies (particularly Mataranka springs and Roper River).

In line with the discussion above, current groundwater management rules in the Northern Territory should be urgently updated, so that they ensure protection of the groundwater dependent values sustained by the CLA and any other groundwater resources. Updated groundwater management rules set out in the WAPs currently being developed should firstly outline clearly the key groundwater dependent values of each region, and/or the connectivity between extraction within the relevant plan area, and other regions of the CLA where the groundwater sustains key values. Secondly, the WAPs should document how adverse impacts to these values are to be monitored and prevented, informed by rigorous baseline studies and modelling - e.g., to determine minimum groundwater levels and flow rates (as well as quality) required to sustain river baseflow, springs, stygofauna, groundwater dependent vegetation, and access to groundwater and surface water for other purposes/users. This must include thorough scientific work to address knowledge gaps regarding the ecological, cultural and water use values sustained by CLA groundwater in the Georgina and Wiso Basins, where data and knowledge are to date relatively lacking. The following is a brief review of groundwater management approaches adopted elsewhere in Australia to provide context in support of the proposed updated management regime outlined below ('A path to sustainable groundwater management in the CLA'):

Approaches to sustainable groundwater management

Approaches to groundwater management in Australia and internationally vary considerably (Cook et al., 2023); however, many jurisdictions set regional and/or local caps on extraction volumes from a given aquifer, terming this a 'sustainable yield' or some variation (e.g., 'Permissible consumptive volume' in Victoria). Approximately half of the groundwater management areas declared in Australia adopt a limit on volumetric extraction rates of this kind (Barnett et al., 2020). In many of these districts, water trading is also permitted between users within the groundwater management area, provided total extraction rates stay below the overall cap for the aquifer. In some regions (such as the Lower Burdekin in Queensland), extraction rate limits can change depending on other variables – such as the salinity of groundwater, to mitigate the risk of saline intrusion (Thomann et al., 2020). Water trading may also be used as a mechanism to encourage water use away from areas where it may risk causing adverse consequences, into areas considered low-risk (e.g. Southern Rural Water, 2010).

The determination of extraction cap limits within different groundwater management areas relies on different approaches, depending on jurisdiction (Cook et al., 2023). Many states (such as NSW, Victoria and WA) have commissioned state-wide reviews into appropriate sustainable yields for different aquifer systems and have used these as the basis for setting or adjusting extraction rate limits. In some areas where groundwater extraction is already intensive, and there are significant values at stake (such as groundwater flows to surface water), numerical modelling is used to determine allocation rates, such as for the Namoi alluvial aquifer, one of the most intensively utilized groundwater resources in Australia (NSW Government, 2019). The region with the greatest number of groundwater management areas (and greatest cumulative extraction volumes) in Australia is the Murray Darling Basin. According to the methodology adopted by the Murray Darling Basin Authority in its 2012 Basin Plan, caps on rates of groundwater extraction - termed Sustainable Diversion Limits (SDLs) within sub-regions of the basin, are set based on an analysis of the rate of diffuse groundwater recharge, and analysis of the risks of extracting different fractions of this recharge on aquifer integrity, baseflow to streams, groundwater quality, and GDEs. In areas where these risks are deemed high, sustainable yields/SDLs are set at 5% of recharge or

less – in other ‘low risk’ areas, the fraction may be as high as 70%, but this is rare (Walker et al., 2020).

Alternative or complementary groundwater management rules (in addition to volumetric extraction rate caps) include the use of trigger levels, whereby the management objective is to maintain groundwater levels in an aquifer above a threshold required to protect certain values. This is usually designed to achieve either protection of environmental assets (such as groundwater discharge to rivers or springs) or prevent bore interference and loss of access to the resource. A combination of a cap on yearly extraction volumes within a district, plus trigger-based rules which result in a cut to the volumetric extraction cap if levels fall below a certain value, are used in some groundwater management areas to address concerns over both access to the resource, and flow of groundwater to the surface or other aquifers (e.g., Katunga WSPA in Victoria, see Goulburn Murray Water, 2017). There are also examples where conjunctive groundwater-surface water management rules are implemented – e.g., limits on groundwater pumping depending on the distance to a stream (i.e., buffer zones around the stream), and pumping limits that change seasonally to correspond with periods of higher/lower streamflow and thus limit stream depletion (Goulburn Murray Water, 2012). These approaches hold significant potential, when combined with a sustainable yield cap, to balance a desire for groundwater development to support agriculture or other industries, the needs to ensure ongoing access for domestic and stock users, and the health of groundwater dependent surface waters and GDEs.

The Northern Territory’s Arid Zone contingent allocation rule appears to be one of the only cases in Australia where a storage-based approach is applied to the determination of a ‘sustainable’ yield. This may reflect the knowledge that Alice Springs’ town water supply requires far greater rates of extraction than the natural recharge rate (DLRM, 2016), to supply a fundamental need for the township. If this is the rationale for the Arid Zone contingent rules remaining in place in the NT, then it would be straightforward to ratify the Alice Springs Water Control District as exempt from management rules that prevent over-extraction, and allow for continued pumping at greater than the recharge rate in this zone (ideally on a temporary basis while alternative sources are developed). Allowing extraction that depletes aquifer storage to supply adequate drinking water to a major town (a fundamental human need) is very different to allowing such extraction in new areas to supply water for private industry.

The use of the Arid Zone contingent rules or other method that uses a fraction of the total storage volume of the aquifer will not provide the necessary protection required to sustain the ecological and cultural values supported by groundwater in the CLA (as discussed in Section 2) and would lead to damage or (potentially) complete loss of GDEs and access to the resource for existing water users. In the case of the Georgina-Wiso Water Allocation Plan, the current proposal to allow yearly extraction of 40% of the (poorly constrained) long-term average recharge would effectively allow ongoing depletion of aquifer storage in this system, due to the highly episodic nature of recharge. The associated impacts of such depletion (which could be expected to continue for years or decades between significant recharge events) have not been addressed in the draft WAP.

Due to the relatively sparse population and infrastructure in the Georgina and Wiso basins, it is probable that groundwater extraction for irrigation, oil and gas development would be initially concentrated in particular geographic areas, e.g., where road infrastructure allows easy access. Hence, the extraction of groundwater under the ESY proposed in the draft plan would be unlikely to be evenly distributed throughout the WAP area. Modelling the extent of drawdown and the localized impacts of this (such as loss of stygofauna, subsidence and migration of saline groundwater) in scenarios where the ESY rates are concentrated in particular zones should form part of the analysis of the suitability of the ESY, considering this.

A path to sustainable groundwater management in the CLA

The most effective way to manage groundwater to protect the environmental and cultural values sustained by the CLA in the Daly, Georgina and Wiso basins would be a combination of both volume and trigger-level based rules, that encompass:

1. **Volumetric extraction rate limits** which in the long-term ensure:
   a) groundwater flows do not decline in such a way as to compromise the health of the groundwater dependent ecosystems sustained by these flows. This requires careful analysis of recharge and discharge flux rates, environmental dependencies on these flows, and the extent of 'capture' by pumping at different rates in the different CLA basins. The connectivity of the CLA flows to rivers (e.g. the Roper, Flora and Daly) and throughflow across sub-regions and basin boundaries (e.g. the dependence of flows within the Daly basin on inflow from the Georgina and Wiso basins), must be properly considered in this process. Sustainable yields set within a given management area must be shown to be sustainable cumulatively, in conjunction with those set in adjacent WAP areas.

   b) the renewability of groundwater resources, preventing ongoing storage depletion and/or detrimental capture of surface flows, e.g., by not exceeding any significant fraction of the recharge/discharge, in recognition of the high value of groundwater to the maintenance of the Roper River, Mataranka springs and other GDEs and communities.

2. **Clearly defined and well monitored water level triggers/thresholds**, which are determined to be the groundwater elevations required to sustain environmental and cultural values of key groundwater dependent sites and ecosystems. When threshold levels are approached or crossed, reductions in groundwater pumping would be triggered, in line with level-based management approaches adopted in other parts of Australia and internationally. Trigger levels must be set at an appropriate distance from the environmental assets seeking to be protected, to account for time-lags between changes in extraction rates, hydraulic gradients and flow rates in an aquifer. Buffer zones around high value GDEs should be enacted, in which groundwater extraction is restricted and/or not permitted, to minimize the risk of short-term damage that may result from rapid drawdown and/or capture of fluxes near the point of extraction.

A mechanism to adjust the volumetric rates and trigger levels to consider climatic conditions - e.g., periods of unusually low rainfall and high evapotranspiration, following which groundwater levels and fluxes are likely to deplete more rapidly in response to extraction, should also be included. This would align with the intent of the National Water Initiative (Walker et al., 2021).

The setting of appropriate trigger levels requires in-depth eco-hydrological studies to determine the threshold groundwater levels required to maintain flows to springs and rivers, the viability of stygofauna, and access to groundwater by vegetation. Following these studies, a series of trigger levels at various distances from each GDE should be set, with clearly defined monitoring locations. If these threshold levels are approached or crossed, groundwater extractions should (according to management rules) be reduced or ceased until they stabilise or recover above the threshold. This approach should be conducted in conjunction with numerical or analytical modelling, to ensure the trigger points can provide sufficient early warning (incorporating time-lags in response to changes in extraction rates), to protect the GDE (Currell, 2016; Noorduijn et al., 2019). This combination of flux and trigger-based management values would align with current best practice for sustainable groundwater management (Thomann et al., 2020).

Proper determination of the appropriate extraction rate limits and triggers to satisfy both 1) and 2) in each WAP (and cumulatively), will require further scientific work, including both field studies and modelling, to establish and monitor:

- Recharge rates throughout the CLA and its sub-basins and zones (particularly where these are not already well constrained), including recharge from streams, lakes and karst structures
- Discharge fluxes from the aquifer to the surface, and between different basins (i.e., throughflow, which remains poorly constrained, and vertical inter-aquifer leakage)
- The environmental dependencies on water levels and discharge fluxes from the CLA (i.e., ecohydrological studies)
- How extraction at different rates, and in different regions, changes both groundwater levels and discharge fluxes, including the timescales and spatial distribution of these responses
- Different GDEs' tolerance for changes in both groundwater levels at different locations, and groundwater discharge fluxes (flow rates)

The combination of strategies and rules described above is the only clear path to sustainable aquifer management in the Cambrian Limestone Aquifer and Beetaloo sub-region.

Setting a sustainable yield for the Tindall Limestone aquifer

Under the current water allocation planning framework rules, the Tindall Limestone aquifer (which is critical for maintenance of the Mataranka Springs, Roper and Flora rivers and other GDEs) falls in the Top End zone, and as such, a default position for setting a volumetric cap on extractions would be 20% of the Basin's estimated recharge (i.e., approximately 66 GL/year). Bruwer and Tickell, 2015 conducted modelling of groundwater extraction from Daly Waters to Mataranka under this scenario, involving an additional 40 GL/year of extraction surrounding Larrimah, plus the existing 26 GL/yr of licensed extractions in the CLA to the north (predominantly near Mataranka). This modelling indicated that in the long term, the additional pumping would result in an approximately 20% reduction in flows in the Roper River, following an equilibration period of approximately 300 years. The environmental and cultural significance of these flow reductions was not assessed, and it has not been determined whether 20% reduction in baseflows, particularly during particularly dry years, could have significant detrimental impacts on ecological and/or cultural values of the Roper River. Analysis by Jolly et al., (2004) indicated that in years of below average rainfall, such reductions may jeopardise GDEs and cause significant saltwater ingress up the Roper River.

A previous draft of the Mataranka Tindall WAP from 2012 proposed the use of 15% of recharge as an extraction cap, which (if applied over the whole Tindall Limestone aquifer) would equate to approximately 50 GL/year. Determining the effect on baseflows to the Roper River, Mataranka Springs and other GDEs, and assessing the associated risk from ecological, cultural and water resources viewpoints, would be important to determine if this is an appropriate extraction cap. Should the dependence of ecological and cultural values of these sites during dry periods be put at risk, lower fractions of recharge should be considered.

One way to help determine appropriate sustainable yields is through numerical modelling, noting that Knapton (2020) completed major FEFLOW-MIKE11 coupled groundwater/surface modelling of the CLA, designed to aid current and future assessment of groundwater abstraction scenarios. The impetus for the modelling was the recommendations of the Pepper Inquiry, including that there was a need for "development of a regional groundwater model to assess the effects of proposed water extraction of the onshore shale gas industry on the dynamics and yield of the regional aquifer system." A key aspect of the modelling was also to enable water planning to conduct predictive uncertainty analysis to help determine the level of confidence with which the impacts of extraction at given rates could be made.

The draft Georgina Wiso WAP appears to have involved further modelling, based on the work of Knapton (2020), to inform the recharge rate used to calculate the proposed ESY. The precise changes to the previous model and/or updates in modelling assumptions are not clear from the plan's documentation.

It should be noted that numerical modelling is only as robust as the field data used to develop its conceptual elements and parameters. Most of the key knowledge gaps discussed above and below in this report still require additional field studies, before modelling can be considered reliable to predict impacts within acceptable ranges of uncertainty. This is important due to current limitations acknowledged in the modelling – e.g., it is based on conventional porous media flow, whereas it is known that flow in the CLA is predominantly through secondary porosity, and water balance/budget estimates and inter-aquifer connectivity remain relatively poorly constrained through most of the region (Knapton, 2020).

Sustainable management regimes for other management zones in the CLA

Key considerations in the setting of extraction caps in the southern CLA basins – i.e., Georgina Basin and Wiso Basin, are:

a) Current uncertainty in the recharge rates for these basins (the rates are not well constrained and there is evidence recharge may occur by both diffuse and preferential mechanisms – see Deslandes et al., 2019; de Caritat et al., 2019).
b) Lack of understanding of the major groundwater discharge mechanism(s) in these basins (e.g. spring discharge, diffuse ET losses, inter-aquifer leakage). These discharges are likely to be significantly changed by a large increase in groundwater extraction rates - as the capture of discharge is often the dominant long-term consequence of groundwater extraction. The environmental, social, cultural and economic consequences of increases in extraction can't be determined until the pre-existing baseline, and changes to this are properly understood.
c) Uncertainty over the extent of throughflow from the two basins into the Daly Basin (Tindall Limestone) and likely flow-on effects to GDEs in the Tindall Limestone if these throughflow volumes decline and/or reverse over time.
d) The potential for irreversible loss of storage and/or reductions in aquifer transmissivity, causing subsidence and aquifer compaction, if groundwater levels substantially decline.
e) The extent of damage to stygofauna communities (e.g., Oberprier et al., 2021) that may occur under different levels of drawdown in these basins.
f) The likelihood of migration of saline groundwater into areas of fresher groundwater under the influence of intensive groundwater extraction in particular areas.

Mechanisms to ensure the following are also critical to ensure rigor and trust in groundwater management processes:

- The scientific basis for the setting of sustainable yields, trigger levels and any other groundwater management rules must be clear and transparent, and any supporting datasets and modelling made publicly available.
- Ample opportunities for input to the design of the management rules from the public and key stakeholder groups, e.g., Traditional Owners and conservation groups who can speak to the value of the ecosystems and waters sustained by the aquifer(s) and what is at stake if these are lost.
- Participation of independent scientific and water policy experts in the process of reviewing and developing science-based management rules to protect values identified as being in need of protection.

4. Identify key gaps, misinterpretations and inconsistencies in the existing data, science, interpretation, analysis, modelling and conclusions Identify the critical science requirements for robust water allocation.

As discussed above, the setting of new/updated groundwater management rules that can ensure protection of the values sustained by the CLA requires a significant amount of scientific data and analysis, to address current knowledge gaps. In response to the Pepper Inquiry's recommendations, a program of scientific work – the Strategic Regional Environment and Baseline Assessment (SREBA), has been underway since 2018, attempting to address knowledge gaps raised in the inquiry and those highlighted in this report (Table 5):

Topic	Anthony Lagoon Formation	Gum Ridge Formation	Basalt	Neoproterozoic sandstones
Water level network	MODERATE	GOOD	POOR	POOR
Water quality network	MODERATE	GOOD	POOR	POOR
Aquifer connectivity	POOR	POOR	POOR	POOR
Aquifer extent and thickness	MODERATE	GOOD	MODERATE	POOR
Aquifer parameters	MODERATE	MODERATE	MODERATE	POOR
Recharge and discharge processes	POOR	GOOD	POOR	POOR

Table 5: Hydrogeological knowledge gaps identified in the SREBA review, as of 2021 (Northern Territory Government, 2021).

Key gaps requiring additional data and knowledge, which (according to the above) are currently being addressed through ongoing studies include:

- More detailed quantification of groundwater recharge and its mechanisms/processes in the three CLA sub-basins
- Better understanding of inter-aquifer connectivity and likely fluxes between different layers and units within and across the three CLA Basins.
- Further data characterising aquifer and aquitard hydraulic properties
- A greatly improved monitoring network for both water quality and quantity, encompassing nested sites allowing for analysis of inter-aquifer connectivity.

Scientific work is also required to address further issues identified in this review, in order to implement a robust groundwater management regime. It is unclear to what extent the SREBA or other programs are going to address these:

- Eco-hydrological studies to determine threshold groundwater levels and flow gradients required to sustain discharge flows to the Roper River, Mataranka Springs, Flora River springs and other GDEs – such as vegetation sustained by permanent access to shallow groundwater. Such studies are required both to inform details of updated groundwater management rules, and to establish appropriate monitoring programs that can document changes to GDEs and allow for informed actions to protect these.
- More data and information about the springs of the Flora River and those on the western margin of the Wiso Basin (Top Springs), e.g., documenting rates of discharge, source aquifer(s) and vulnerability to depletion due to up-gradient groundwater extraction.
- A more in-depth analysis of the major current mechanism(s) of groundwater discharge from the Georgina and Wiso basins (encompassing the above, as well as diffuse inter-aquifer leakage, ET by vegetation communities and un-documented springs and stream baseflow), to determine what the likely long-term impact of

increased groundwater extraction is within these relatively under-characterised aquifer systems.

- Determining hydrological and water quality requirements of stygofauna, and analysis of the extent to which these subterranean ecosystems may be impacted by groundwater extraction at different rates in different regions
- The likely time scales of the responses of aquifers to extractions at different rates and locations, and how the response evolves through time (e.g. proportions of storage depletion vs stream/spring depletion caused by pumping, and how this changes through time)
- The importance of episodic recharge, particularly in the southern CLA basins, and the likely recurrence interval for major recharge events, which provide the majority of water to the aquifers over the long-term.
- The likely impact of climate change on groundwater recharge rates and mechanisms, groundwater discharge (e.g., via evapotranspiration) and flow-on effects to GDEs.

At present, existing knowledge gaps prevent a comprehensive analysis of the likely impacts of groundwater extraction from the CLA at different rates and in different areas on the key environmental and cultural values the aquifer sustains, or the adoption of appropriate caps on groundwater extraction rates and trigger levels to protect GDEs and river baseflows. Finalising the CLA / Beetaloo WAPs, and making future groundwater licensing decisions in a manner that is scientifically robust, will require these gaps to be (urgently) addressed.

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Appendix A: List of questions/topics to address in this report (Environment Centre NT)

1. **Using publicly available scientific reports (which have been collated by the Environment Centre NT and will be provided to you) develop a conceptual understanding of the Cambrian Limestone aquifer, including:**

   a. The hydrogeological structure of the Cambrian Limestone Aquifer (including the configuration, geometry and hydraulic properties);

   b. The water balance components and their dynamics for key groundwater systems, including inputs (eg recharge from rainfall events or leakage from rivers, groundwater inflows from other aquifers), through-flow (eg definition of groundwater flow paths, watertable and groundwater level contours) and outputs (eg spring discharge, baseflow to rivers, evapotranspirative use by vegetation, outflow to other aquifers, groundwater pumping); and

   c. The dependencies on the key groundwater systems from the hydrological perspective (eg groundwater discharge maintaining river flows), environmental perspective (ie ecosystems reliant on groundwater such as vegetation accessing shallow groundwater, aquatic ecosystems in springs and groundwater-fed rivers) and cultural perspective.

2. **Advise on the risks to dependencies (particularly the Mataranka springs complex and the Roper River) of utilising:**

   a. the Arid Zone contingent allocation rules in the NT Water Allocation Planning Framework as the basis for establishing an "estimated sustainable yield" in the Beetaloo Basin (with specific reference to the proposed Mataranka Tindall Water Allocation Plan and the Georgina Basin Water Allocation Plan);

   b. an "estimated sustainable yield" based on a significant proportion of storage of the Cambrian Limestone Aquifer or its constitutive aquifers (with specific reference to the asserted estimated sustainable yield of 40% of the storage of the Gum Ridge Formation identified in the APPEA fact sheet).

3. **Advise on how an "estimated sustainable yield" should be calculated for the purposes of water allocation plans in the Beetaloo Basin** to safeguard against risks to dependencies (particularly the Mataranka springs complex and the Roper River).

4. **Identify key gaps, misinterpretations and inconsistencies in the existing data, science, interpretation, analysis, modelling and conclusions**. Identify and prioritise the key sources of uncertainty relating to the hydrogeological architecture, water balance, groundwater dependencies and risks from existing and potential resource development, and the science needs to reduce these uncertainties. Identify the critical science requirements for robust water allocation.

The Hon. Natasha Fyles
Northern Territory Chief Minister

23 November 2022

Dear Chief Minister

Re: Poor practice water planning in the Northern Territory

As a group of Australian water experts, we express our concerns about the Northern Territory's approach to water planning and regulation. The Northern Territory's record of water planning does not meet national standards, reflected in recent departures from the principles of national water policy (see attachment).

Progress in rolling out water allocation plans (WAPs) has been extraordinarily and unacceptably slow. As a result, most of the water licenced to industry has been done so outside of a statutory planning process. Further, current licencing primarily addresses needs of individual projects, with insufficient transparent or rigorous assessment of cumulative impacts.

We have considerable concerns about the Contingent Allocation Framework. First, NT's continued reliance on 'contingent allocation rules' over the 95% of the NT not covered by water plans entrenches poor practice and undermines water planning outcomes and processes. We also hold concerns about the use of climatic zones within the framework and the criteria applied to assessing the 'sustainable yield' in the Arid zone. The reliance on water storage volumes to calculate sustainable yield is out of step with sustainable groundwater management principles. Other Australian jurisdictions do not use this method to assess sustainable yield. The largely default Contingent Allocation Framework needs to be replaced by a scientifically defensible and transparent practice of comprehensive water planning.

The recently released *Georgina Wiso Water Allocation Plan (2022-2030)* is particularly poor and regressive. It breaches water planning guidelines of the National Water Initiative (NWI), committed by all jurisdictions and the Australian Government. It risks many significant environmental and Indigenous values. No water advisory committee was put in place, compounding the problem of absent environmental or cultural requirements for water or trigger rules for assessing unacceptable impacts. Potential impacts to groundwater dependent ecosystems are completely overlooked. The scientific and procedural deficiencies identified in the attachment to this letter need to be addressed, supported by a robust program of technical studies, review, and input from the scientific community – in the public domain.

We understand that the NT Government has committed to replacing the *Water Act 1992 (NT)* with modern legislation by 2026. This is an unacceptable timeframe, not least of all because environmental and cultural values will be compromised by deficient WAPs that are adopted in the interim. We therefore urge you to urgently implement the following:

- Halt issuing water licences inside and outside WAP areas until data on groundwater-surface water interactions and the water requirements of ecological and cultural values

have been comprehensively obtained to ensure integrity and transparency in water planning and allocation processes;

- Dedicate resources to developing extensive baseline science for large, data-poor regions, such as the Cambrian Limestone Aquifer, and more robust monitoring programs for all WAPs;
- Establish consultative committees for the Georgina Wiso and all future WAPs to ensure that all voices are heard in the water planning process and processes of scientific and public review are guaranteed;
- Obtain resources in accordance with NWI principles of cost recovery to develop a more rigorous scientific basis for determining sustainable yields for groundwater, including gaining a far better understanding of groundwater recharge, discharge/outflows and inter-aquifer connectivity;
- Undertake detailed supporting modelling (informed by comprehensive field data) to show how extraction at different proposed ESYs and in different regions of the Beetaloo Basin would be likely to alter groundwater conditions and connected values;
- Set aside provisional Aboriginal Water Reserves for all aquifers and catchments prior to the completion of WAPs to avoid water over-allocation; and
- Reform NT water legislation to ensure that WAPs are legally binding on decisions of the Water Controller to issue water licences.

Yours faithfully

Professor Sue Jackson, Australian Rivers Institute, Griffith University
Professor Matthew Currell, School of Engineering, RMIT University
Emeritus Professor Barry Hart, Monash University
Dr Erin O'Donnell, Law School, University of Melbourne
Dr Chris Ndehedehe, Australian Rivers Institute, Griffith University
Professor Jenny Davis, Research Institute Environment & Livelihoods, Charles Darwin University
Professor Richard Kingsford, Centre for Ecosystem Science, University of NSW and Wentworth Group of Concerned Scientists
Professor James Pittock, Australian National University and Wentworth Group of Concerned Scientists
Adjunct Professor Brad Pusey, School of Biological Sciences, University of Western Australia
Professor Jeff Connor, Business School, University of South Australia
Professor Marcia Langton, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne
Professor Anne Poelina, Nulungu Research Institute, University of Notre Dame
Associate Professor Rebecca Nelson, Law School, University of Melbourne
Professor Mark Kennard, Australian Rivers Institute, Griffith University
Dr Emma Carmody, Lawyer, Wentworth Group of Concerned Scientists
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Associate Professor Gavin Mudd, School of Engineering, RMIT University
Professor Quentin Grafton, Crawford School of Public Policy, Australian National University

Background and supporting material

Almost twenty years ago the Northern Territory signed up to national water policy, the National Water Initiative, which commits jurisdictions to 'nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes' (COAG 2004, clause 23).

Since that time the NT has seen an acceleration in water extraction and heightened interest in exploiting the region's water resources (including involvement with large-scale gas production in the Beetaloo Basin). Water licence decisions are increasingly controversial and contested with several being the subject of legal review. The need for robust and transparent water planning has never been greater.

Water allocation planning is the central organising device through which the National Water Initiative is to be delivered. Water plans provide a transparent means by which the sustainable yield is estimated, beneficial uses quantified, environmental and cultural requirements and protections identified, trade-offs negotiated, and implementation strategies agreed. The definition of environmental sustainability is to be determined by a community process that takes full account of social, economic and environmental issues. Across Australia public participation has been guaranteed through advisory bodies that provide a forum deliberating over the effects of water use on matters of public interest. In the Northern Territory WAPs also provide the legal trigger to the establishment of Strategic Aboriginal Water Reserves (where there is eligible Aboriginal land). Ideally the planning process provides a mechanism for putting all water users on an equal footing and limiting their collective use to sustainable limits.

Yet progress in rolling out water allocation plans (WAPs) in the Northern Territory has been very slow and in most of the NT water managers do not have a thorough understanding of how much water can be sustainably used. Only six plans are currently in effect, covering approximately 5% of the NT[1] and several others are in development. Many WAPs are taking an extremely long time to complete. For example, the Howard River WAP has been in development since 2010, although concerns about environmental impacts of water management practices in the region have been publicly aired since 1998, and the Mataranka Water Allocation Plan (still in draft) has a similar history[2].

As a result, most of the water licenced to industry has been done so outside of a statutory planning process. According to the Productivity Commission[3], only 28% of water licences occur in WAP areas; a figure that compares very poorly with the national average of 80%. The current licence assessment process is tailored to addressing the needs of individual projects

[1] Nikolakis W. & Q. Grafton (2021). Law versus justice: The Strategic Aboriginal Water Reserve in the Northern Territory, Australia. *Australia International Journal of Water Resources Development* 1–19.

[2] O'Donnell, E., Jackson, S. Langton, M. & L. Godden (2022). Racialized water governance: the 'hydrological frontier' in the Northern Territory, Australia. *Australasian Journal of Water Resources* 26(1): 59-71.

[3] Productivity Commission (2021). *National Water Reform 2020: Productivity Commission Final Report, Canberra*.

with little opportunity to assess the cumulative impacts transparently or rigorously[4]. Elsewhere, such licence-by-licence approaches have been shown to be ineffective[5] and, in our view, the NT's continued reliance on 'contingent rules' is entrenching this practice and undermining water planning outcomes and processes.

The vast spaces of the NT that are not governed by a WAP are subject to the 'Contingent Allocation Framework' which has been in place for twenty years. This policy was based on a rule of thumb referred to as the 80:20 rule which establishes an arbitrary limit on water use from surface and groundwater resources. The rule has enabled the government to continue to allocate water, presumably with the expectation that an 80:20 split would be sufficient to conserve the NT's rivers, wetlands, springs and the groundwaters sustaining them. We are concerned that a policy which appears to have been introduced as an interim measure has become the default framework for water licencing over most of the Northern Territory.

The climatic zones within the Contingent Allocation Framework and the criteria applied to assessing the 'sustainable yield' in the Arid zone is another problematic feature. The Arid zone rule permits 80% of the aquifer's total groundwater storage capacity to be extracted over a century, as long as dependent ecosystems are not harmed. This is a much higher rate of extraction than allowed from the Top End zone. The Arid zone rule has been closely scrutinised by the Larrimah Water Resources Review Panel, the Pepper Scientific Inquiry into Fracking and by independent specialists with hydrogeological and water management expertise, as well as community groups and other stakeholders. These assessments have variously identified weaknesses in the application of the Arid zone rule in several licencing decisions in the Larrimah – Mataranka area and have concluded that reliance on water storage volumes to calculate sustainable yield is out of step with current sustainable groundwater management principles. Such principles are now well established and agreed in the international groundwater science and policy literature. It was acknowledged by the NT Water Controller in 2003 that this rule permitted mining of groundwater[6] and the Pepper Inquiry considered it 'ecologically unsustainable'. No other Australian jurisdiction that we are aware of uses this method to assess the sustainable yield.

The recent announcement relating to the *Georgina Wiso Water Allocation Plan (2022-2030)* for the Beetaloo Basin gives cause for further concern. In our view this new model of water planning represents a significant departure from the tenets of the NWI and puts at risk many significant environmental and Indigenous values. Unlike all other NT water allocation plans, the draft *Georgina Wiso Allocation Plan* has been prepared without input from a water advisory committee, nor does it establish environmental or cultural requirements for water, or trigger rules for assessing unacceptable impacts.

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[4] Hart, B., O'Donnell, E. & A. Horne (2019). Sustainable water resources development in northern Australia: the need for coordination, integration and representation. *International Journal of Water Resources Development*, 36(5): 777–799.

[5] Franks, S., Brereton, D. & C. Moran (2010). Managing the cumulative impacts of coal mining on regional communities and environments in Australia. *Impact Assessment and Project Appraisal* 28:4, 299-312.

[6] https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/Completed_inquiries/2002-04/water/index

Clause 25 (iii) of the NWI states that the parties' water access entitlements and planning framework's should 'be characterised by planning processes in which there is adequate opportunity for productive, environmental and other public benefit considerations to be identified and considered in an open and transparent way'. The NWI Guidelines for Water Plans and Planning Processes expect jurisdictions to 'consult with stakeholders including those within or downstream of the plan area'. Furthermore, sub-section (vi) states that parties should 'identify and acknowledge surface and groundwater systems of high conservation value, and manage these systems to protect and enhance those values'. Environmental outcomes are to be described and appropriate water management arrangements to be defined (S. 37(1)). Water plans are also expected to incorporate 'indigenous social, spiritual and customary objectives and strategies for achieving these objectives wherever they can be developed' (s 52(ii)). None of these steps has been taken in the formulation of the draft *Georgina Wiso Allocation Plan.*

In addition to public input and deliberation, thorough scientific work is needed to address knowledge gaps regarding the ecological, cultural and water use values sustained by Cambrian Limestone Aquifer groundwater in the Georgina and Wiso Basins, where data and knowledge are to date generally lacking. Yet the Plan has been released prior to the conclusion of assessments to be conducted under the Beetaloo Strategic Regional Environmental and Baseline Assessment (SREBA) (a recommendation of the Pepper Inquiry). According to the WAP's Implementation Plan, Indigenous cultural values will be documented *after* significant water use is to be permitted; key cultural sites relying on water resources and their requirements will not be identified until 2026 and other social and cultural values not identified until 2030. The key groundwater dependent values of each region need to be clearly outlined before development commences. For decision makers to approve water extraction in the absence of adequate baseline data runs counter to sound environmental regulation.

The proposed ESY for the Georgina and Wiso Basins is 260,800 ML/year which represents approximately 0.04 percent of total storage or 40 percent of the currently estimated average annual recharge. It must be stressed that the recharge rate is currently poorly constrained, and as such the proposed ESY may actually be a much higher proportion of recharge. It must be stressed that the best available science indicates that recharge to these aquifers is highly episodic (most likely only happening three times in the past 50 years since water level monitoring began) and in most years the ESY will far exceed recharge. The estimated water budget contained in the plan has further questionable figures – such as the assumption of a lack of groundwater discharge/outflow to surface features or use of groundwater by vegetation, which may reflect a lack of appropriate field data and surveys rather than the lack of existence of such outflows. The question of possible impacts to GDEs, including potential surface expressions of groundwater (e.g. at springs in the western Wiso basins), access to groundwater by deep rooted vegetation, or impacts on stygofauna communities, appears to have been completely overlooked in the plan. Similarly, assumptions that there will be a lack of significant impact on groundwater throughflows to the Tindall Limestone at the northern boundary of the plan area, which ultimately sustain the Roper River and Mataranka Springs, is poorly supported or understood at present. These deficiencies could have been addressed, had a robust program of technical studies, review and input from the scientific community – in the public domain – had been conducted to support drafting of the plan.

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 09-Jan-2024

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	21
Listed Migratory Species:	13

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	18
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	1
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	1

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Status of Conservation Dependent and Extinct are not MNES under the EPBC Act. Number is the current name ID.		
Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat likely to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
[Polytelis alexandrae](#) Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat may occur within area
[Rostratula australis](#) Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
[Tyto novaehollandiae kimberli](#) Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
MAMMAL		
[Macroderma gigas](#) Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
[Macrotis lagotis](#) Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
[Saccolaimus saccolaimus nudicluniatus](#) Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat may occur within area
[Trichosurus vulpecula arnhemensis](#) Northern Brushtail Possum [83091]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
[Acanthophis hawkei](#) Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
[Elseya lavarackorum](#) Gulf Snapping Turtle [67197]	Endangered	Species or species habitat may occur within area
[Tiliqua scincoides intermedia](#) Northern Blue-tongued Skink [89838]	Critically Endangered	Species or species habitat known to occur within area
[Varanus mertensi](#) Mertens' Water Monitor, Mertens's Water Monitor [1568]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
[Varanus mitchelli](#) Mitchell's Water Monitor [1569]	Critically Endangered	Species or species habitat may occur within area
SHARK		
[Pristis pristis](#) Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
[Apus pacificus](#) Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Marine Species		
[Pristis pristis](#) Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area
Migratory Terrestrial Species		
[Cecropis daurica](#) Red-rumped Swallow [80610]		Species or species habitat may occur within area
[Cuculus optatus](#) Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
[Hirundo rustica](#) Barn Swallow [662]		Species or species habitat may occur within area
[Motacilla cinerea](#) Grey Wagtail [642]		Species or species habitat may occur within area
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
[Calidris acuminata](#)		
Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat likely to occur within area
[Calidris ferruginea](#)		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
[Calidris melanotos](#)		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
[Charadrius veredus](#)		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
[Glareola maldivarum](#)		
Oriental Pratincole [840]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State
Unknown	
Commonwealth Land - [70922]	NT

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
[Actitis hypoleucos](#)		
Common Sandpiper [59309]		Species or species habitat known to occur within area
[Anseranas semipalmata](#)		
Magpie Goose [978]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat likely to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Cecropis daurica as Hirundo daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat may occur within area overfly marine area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area

Scientific Name	Threatened Category	Presence Text
Hirundo rustica		
Barn Swallow [662]		Species or species habitat may occur within area overfly marine area
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato)		
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area overfly marine area
Reptile		
Crocodylus johnstoni		
Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area

Extra Information

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed

Geological and Bioregional Assessments

Name	State	Website
Beetaloo GBA region	NT	GBA website

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

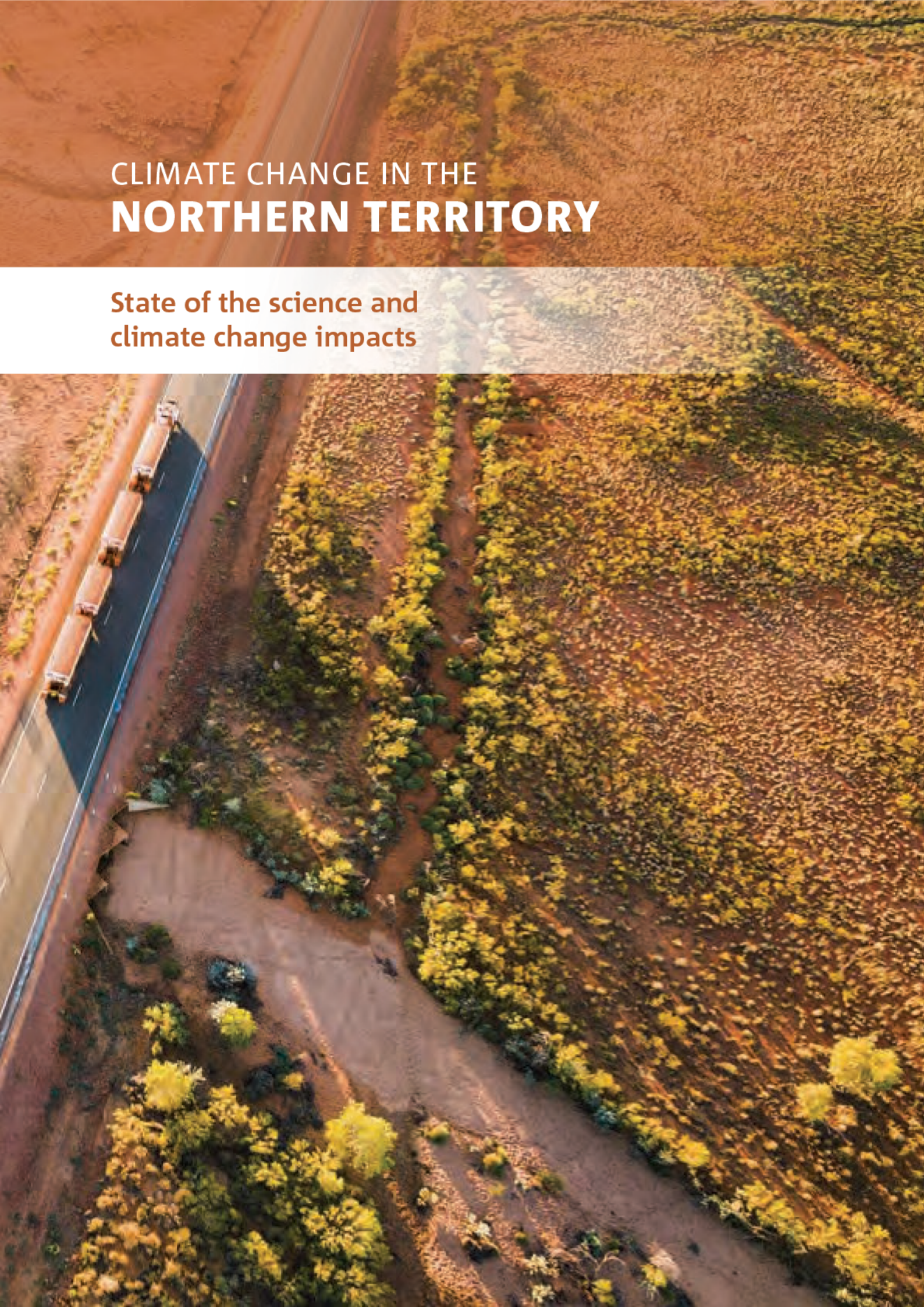
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CLIMATE CHANGE IN THE NORTHERN TERRITORY

State of the science and climate change impacts







This report was prepared for the Northern Territory Government by the National Environmental Science Program Earth Systems and Climate Change Hub.

The Hub is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and is a partnership between CSIRO, Bureau of Meteorology, Australian National University, Monash University, University of Melbourne, University of New South Wales and University of Tasmania. The role of the Hub is to ensure that Australia's policies and management decisions are effectively informed by Earth systems and climate change science, now and into the future. For more information visit www.nespclimate.com.au.

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AT A GLANCE

This report provides Territorians with an easy-to-understand summary of climate change: what it is, how it's affecting the Territory and what we can do about it.

The global climate is changing

Since the Industrial Revolution in the late 1700s, increasing concentrations of greenhouse gases have enhanced the greenhouse effect of the atmosphere, warming the planet. As concentrations of greenhouse gases increase in the atmosphere, so too does the warming. The consequent imbalance of energy in the climate system is causing it to change at an unprecedented rate.

> See Section 1 for more information

The Northern Territory's climate is changing

The Northern Territory's climate is shaped by weather systems and large-scale climate drivers that vary over space and time. This natural variability is now occurring against the backdrop of global climate change, and the climate of the Northern Territory is changing as a result. The extent of the changes to temperature, rainfall and other climate variables will depend on greenhouse gas concentrations in the atmosphere, with higher concentrations leading to larger changes.

In the future:

- The Northern Territory will continue to get warmer.
- The hottest days in the Northern Territory will be hotter and more frequent, and warm spells will be longer. Frost days will decrease.
- Both wetter and drier futures are plausible, depending on greenhouse gas concentrations.
- Heavy rainfall events will become more intense.
- Time spent in droughts could increase, with changes in drought frequency and intensity.
- Tropical cyclones are projected to become less frequent but more intense.
- Fire weather is projected to become more frequent and harsher.
- Potential evaporation will increase.
- Relative humidity is projected to decrease.
- Mean sea level will continue to rise, and the height of extreme sea levels will increase.
- Sea surface temperature will continue to increase, and the number and intensity of marine heatwaves will increase.
- The ocean around Australia will become more acidic at a rate linked to carbon dioxide concentrations in the atmosphere.

> See Section 2 for more information

Impacts on the Territory

Our environment, communities and economy are all vulnerable to the changing climate. Many aspects of Territory life are already being impacted. Identifying and understanding these impacts is critical for planning for the future – to reduce the risk of ongoing or more severe impacts and to identify opportunities for Territorians to build more resilient communities, develop a sustainable economy and maintain healthy natural systems.

> See Section 3 for more information

Responding to change

Territorians need to actively respond to the changing climate in order to maintain sustainable and resilient communities, a healthy environment and a strong economy. Broadly, responding to climate change involves reducing greenhouse gas emissions to limit further change and doing things differently to manage the change that is unavoidable. Individuals, communities, industries and government all have a part to play, and there are a number of resources available to help.

> See Section 4 for more information

1. The global climate is changing

Since the Industrial Revolution in the late 1700s, increasing concentrations of greenhouse gases have enhanced the greenhouse effect of the atmosphere, warming the planet. As concentrations of greenhouse gases increase in the atmosphere, so too does the warming. The consequent imbalance of energy in the climate system is causing it to change at an unprecedented rate.

1.1 The climate system

The climate system is a complex web of five interconnected components and the interactions between them: the atmosphere, the hydrosphere (oceans, lakes, rivers), the cryosphere (ice, snow), the lithosphere (the land) and the biosphere (living things) (Figure 1.1). The interactions between the components are 'forced' by, among other things, energy from the sun and by human activities.

Weather or climate? It's a matter of time

Weather and climate are words often used interchangeably; however, although they are closely related, they are not the same thing. Weather refers to current atmospheric conditions at a particular place and time – what it's like when you look out your window (e.g. sunny, stormy, hot, humid). Climate is the combination of all the weather (from the typical weather to the extremes) for a particular place over decades – usually 30 years. It is often said that climate is what you expect, and weather is what you get!

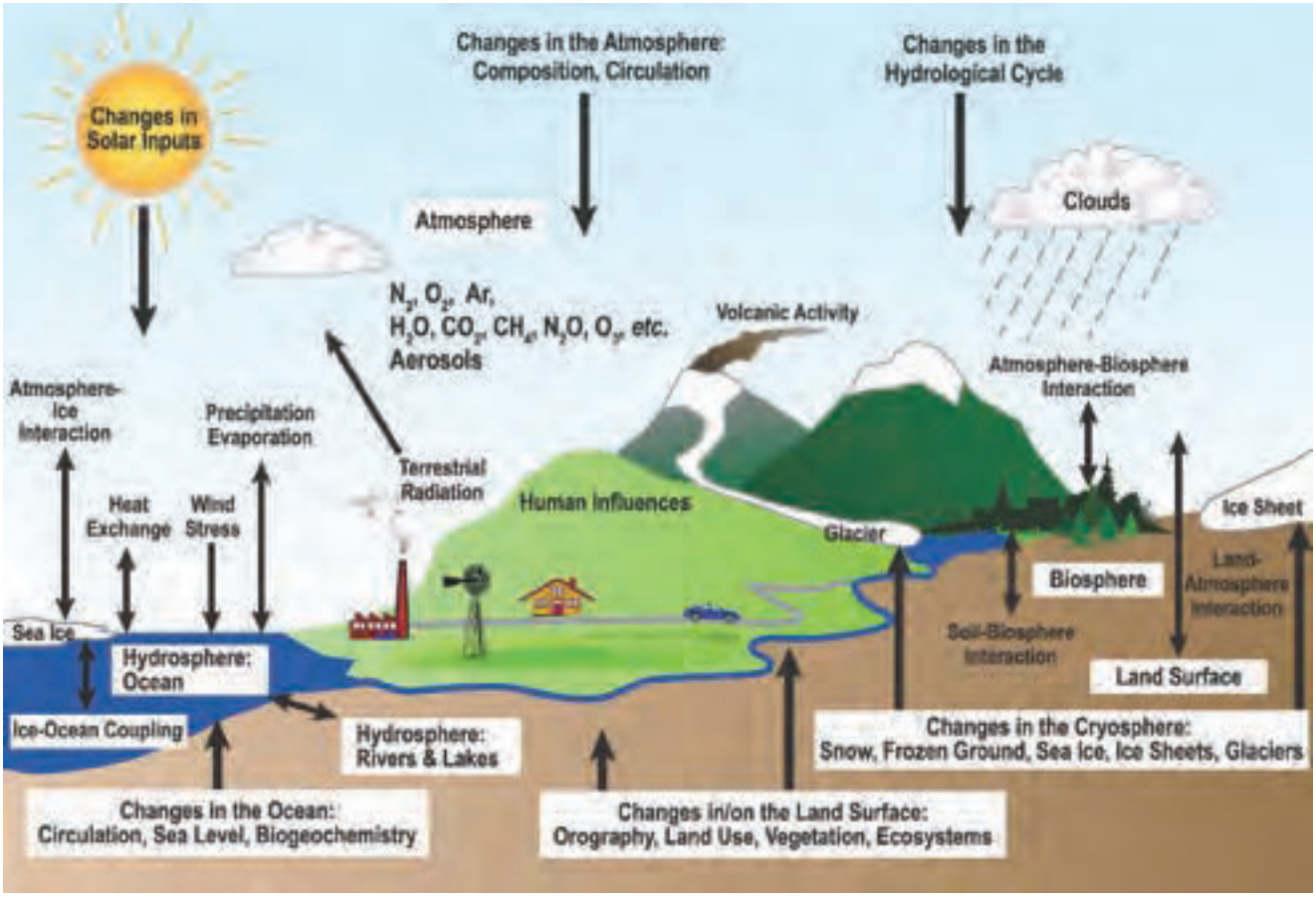


Figure 1.1. The climate system, showing its five components and the key interactions between them (IPCC 2007).

1.2 The greenhouse effect and greenhouse gases

Energy from the sun warms the Earth's surface, causing it to radiate heat in the form of infrared radiation. Most of this heat is absorbed in the Earth's atmosphere and escapes by radiation out to space, but some is trapped by greenhouse gases. The heat that is trapped keeps the Earth warm. This process is called the greenhouse effect (Figure 1.2). Without the greenhouse effect, the average global temperature would be around –18°C and life as we know it would not exist here.

Water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most important naturally occurring greenhouse gases. Water vapour is the most abundant greenhouse gas, but its concentration is not directly influenced by human activities and it is relatively short-lived, staying in the atmosphere for only hours to weeks. The amount of water vapour is determined by the temperature of the air, not by emissions from the surface. The other greenhouse gases are long-lived and their concentrations have increased significantly since industrialisation, predominantly through burning fossil fuels. Carbon dioxide accounts for around three-quarters of greenhouse gases emitted into the atmosphere, followed by methane (16%) and nitrous oxide (6.2%) (IPCC 2014).

Measurements taken around the world show that background atmospheric carbon dioxide concentrations are rising, even though there are are seasonal variations (Figure 1.3). These variations depend on location, the uptake and release of carbon dioxide by plants and oceans, and on global atmospheric transport.

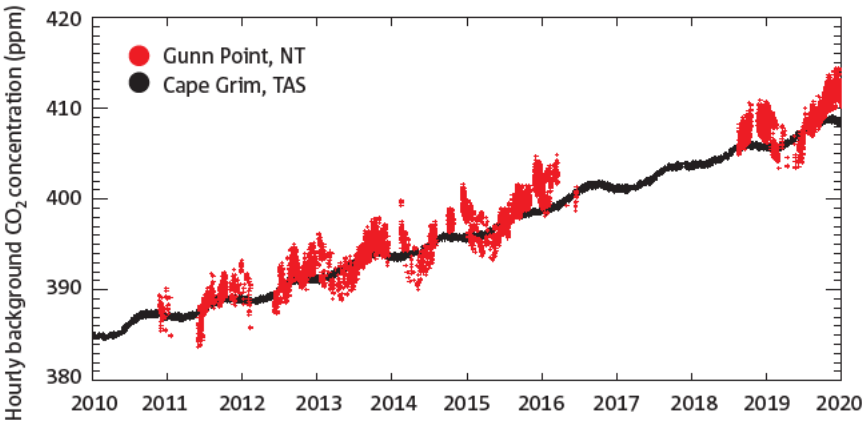


Figure 1.3. Hourly background carbon dioxide as measured at the Northern Territory Baseline Air Pollution Station at Gunn Point and the Cape Grim Baseline Air Pollution Station in Tasmania from 2010 to 2020. (Instruments at Gunn Point were out of commission 2016–2018.)

Greenhouse gases: long lifetimes and lasting effects

It is worth noting that even with cuts in greenhouse gas emissions, the enhanced greenhouse effect will continue for a long time due to the slow removal times of greenhouse gases from the atmosphere. Carbon dioxide increases can persist in the atmosphere for up to thousands of years. Nitrous oxide and methane have much shorter atmospheric lifetimes – around 120 years for nitrous oxide and 12 years for methane – but are both more potent greenhouse gases than carbon dioxide (US EPA, n.d.).

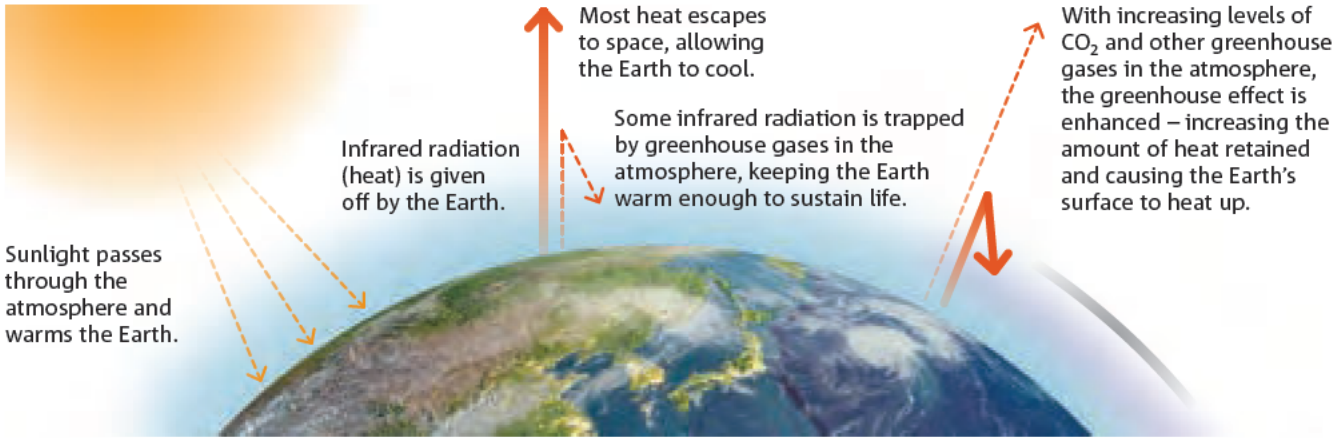


Figure 1.2. The main features of the greenhouse effect. This effect has been enhanced by human activities that have increased the concentration of greenhouse gases in the atmosphere.

1.3 The enhanced greenhouse effect and climate change

Before industrialisation, the average temperature of the Earth was around 15°C. Since then, the increase of greenhouse gases in the atmosphere has enhanced the greenhouse effect, warming the surface of the planet on average by around 1°C (WMO 2020).

The warming is not only increasing air temperatures. Much of the extra heat and carbon dioxide in the atmosphere is being absorbed by the oceans, making them warmer and changing ocean chemistry. As water heats it expands which, along with melting ice sheets and mountain glaciers, is raising sea levels. Atmospheric circulation patterns are being affected, as is the water cycle, which may lead to changes in the frequency and intensity of droughts and extreme rainfall events.

Simulations of the climate with and without greenhouse gases from human activities show that the warming we are experiencing can only occur when we take increasing concentrations of greenhouse gases in the atmosphere into account (Figure 1.4).

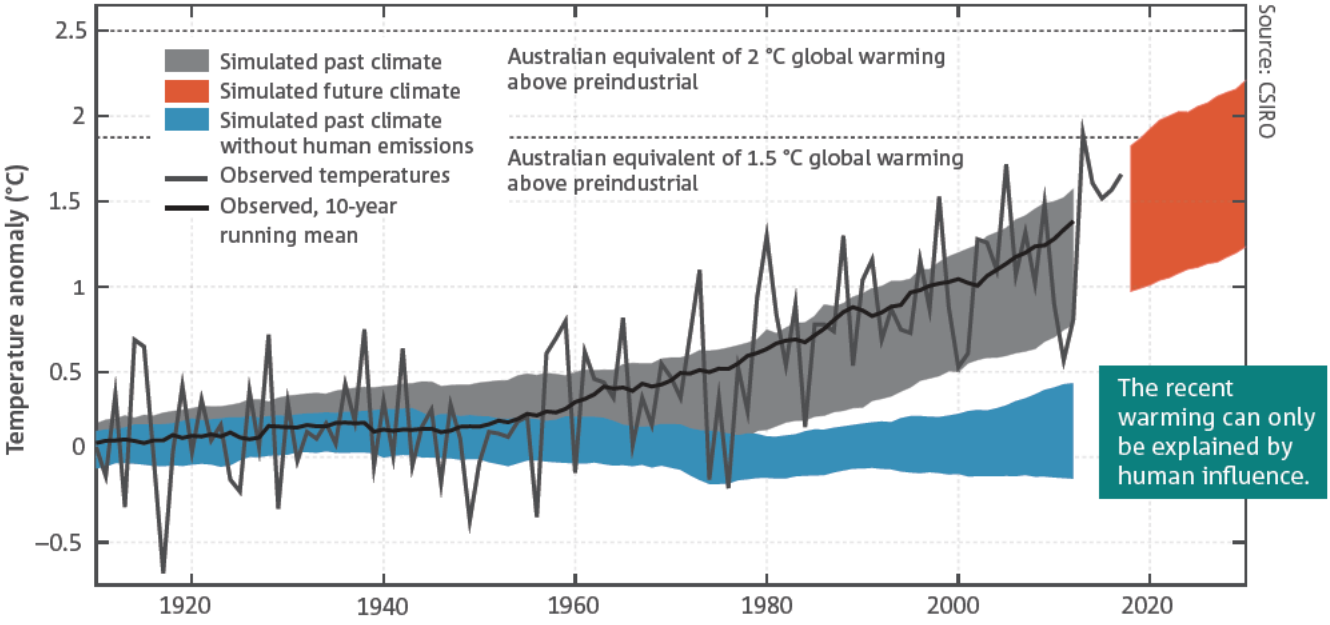


Figure 1.4. Climate simulations without human emissions (blue band) do not match observed changes in the average temperature (grey line). Only simulations that take these emissions into account (grey band) do this. (Source: CSIRO and BoM 2018)

Global assessment and consensus

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations body that assesses climate science from around the world. The results of these assessments are released in major reports that are written and reviewed by hundreds of climate science experts based on thousands of peer-reviewed papers. The most recent assessment report (IPCC 2013) made the following statements:

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.
- Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes.
- It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.
- Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

The consensus among climate scientists that global warming is the result of increasing atmospheric greenhouse gas concentrations has also been demonstrated in other studies (Australian Academy of Science 2015; Cook et al. 2013, 2016). The science is indisputable.

1.4 Understanding current and future climate change

The climate the Northern Territory experiences in the future will be determined by the concentration of greenhouse gases in the atmosphere and how the climate system responds to the changes that are occurring, as well as natural climate variability. We can use climate models to simulate a range of future scenarios and provide climate change projections. Projections can be powerful tools for preparing for the future.

1.4.1 Modelling the climate system

Climate modelling allows us to understand past and current changes in climate and to explore the future climate. A climate model is an incredibly complex computer program. It uses mathematical equations based on the laws of physics that govern the climate system and representations of processes such as turbulence, radiation interaction with atmospheric gases and particles, cloud formation and convective processes to simulate the processes and interactions in the climate system.

Global climate models divide the Earth into a 3-D grid, where each grid cell is around 200 kilometres in size. There are typically 40 layers of these cells in the atmosphere and 50 levels down into the ocean. When the model is run, its equations are solved for one point in time for each cell, then those values are used in the equations for the next point in time and so on – much like in the climate system itself, where what happens at one place at one point in time influences what happens there and at adjoining places for the next point in time. In essence, these models are the same types of models that are used to forecast weather.

Due to the enormous number of computations involved, the models are run on supercomputers. Even with such high-powered computing, the models take some time to run. Simulating Australia's climate for one year can take up to a day on our most powerful supercomputers, depending on the model resolution (that is, the size and number of the grid cells the Earth is divided into).

Because of their relatively coarse scale, the simulations from global climate models do not always pick up finer-scale features and processes that influence regional climate, such as mountains or regional weather systems. Regional climate modelling, also called downscaling, can offer additional detail to global climate model simulations. Climate simulations can be downscaled using statistical relationships between the large-scale and regional-scale climate (statistical downscaling) or by nesting a higher resolution regional model within the relatively coarse global model (dynamical downscaling). While downscaling can offer useful regional detail, downscaled simulations still need to be interpreted in the context of the broader global simulations from which they have been derived.



1.4.2 Representing greenhouse gases in modelling

Atmospheric greenhouse gas concentrations have a significant impact on the climate system, and so need to be included in climate modelling. However, future greenhouse gas concentrations are difficult to determine, as greenhouse gas emissions rely on a range of economic, political, social and technological decisions that we cannot foresee.

To overcome this, the climate science community has developed standard scenarios to use in climate modelling. The Australian national climate change projections (see Section 1.4.4) use scenarios called representative concentration pathways or RCPs. These scenarios allow researchers to simulate the climate under four futures, ranging from very strong mitigation of greenhouse gases (RCP2.6) through to ongoing high emissions (RCP8.5) (Table 1.1). The numbers in RCPs refer to radiative forcing, a measure of the balance of the Earth's energy budget – negative radiative forcing indicates cooling, while positive radiative forcing indicates warming (Department of the Environment, n.d.).

In 2019, the global carbon dioxide equivalent (CO_2-e) concentration (which includes carbon dioxide and other greenhouse gases) was already 500 parts per million – and is rising by about 3 ppm per year (NOAA 2020).

Table 1.1. Comparison of representative concentration pathways. Projected temperature and sea-level change are relative to the period 1986–2005.

RCP	Greenhouse gas concentration in 2100 (CO_2 equivalent, parts per million)[1]	Emissions pathway[2]	Projected average temperature change (°C) in 2100[3]	Projected average sea-level rise (m) in 2100[4]
2.6	490	Emissions peak around 2020	0.3 to 1.7	0.26 to 0.55
4.5	650	Emissions peak around 2050	1.1 to 2.6	0.32 to 0.63
6.0	850	Emissions peak around 2080	1.4 to 3.1	0.33 to 0.63
8.5	1370	Ongoing high emissions	2.6 to 4.8	0.45 to 0.82

(Sources: 1. van Vuuren et al. 2011; 2, 3, 4. IPCC 2013)

1.4.3 What climate change projections tell us

While it is tempting to think of climate projections as long-range weather forecasts, this is not the case. Weather forecasts predict the timing and sequence of particular weather events based on forecasting forward from real-time observations. With this constant updating of information checked against observations, weather models can give very accurate and detailed short-term predictions.

Climate projections cannot give this precise detail over the decades and centuries that they cover. While they can simulate a sequence of future weather events, they do not forecast the exact timing of these events. Rather, they provide much broader scale information about how the whole climate system will respond to different future scenarios. They essentially provide the statistics of future weather, such as what the average temperature might be and how daily or monthly temperatures may vary around it. However, there are some limitations.

One is our understanding of the extent of this natural variability. In some cases, it may hide the changes due to global warming, at least for a while. Another is our understanding of how the climate system will respond to global warming. We are not clear about some of the feedbacks in the climate system, such as changes to cloud cover with ongoing warming, and the extent to which they will enhance the changes that we see.

In all, climate change projections provide the best information available on the range of possible future changes, and a full range of projections (from different models and using a range of RCPs) can provide useful insight into likely future climate risks.

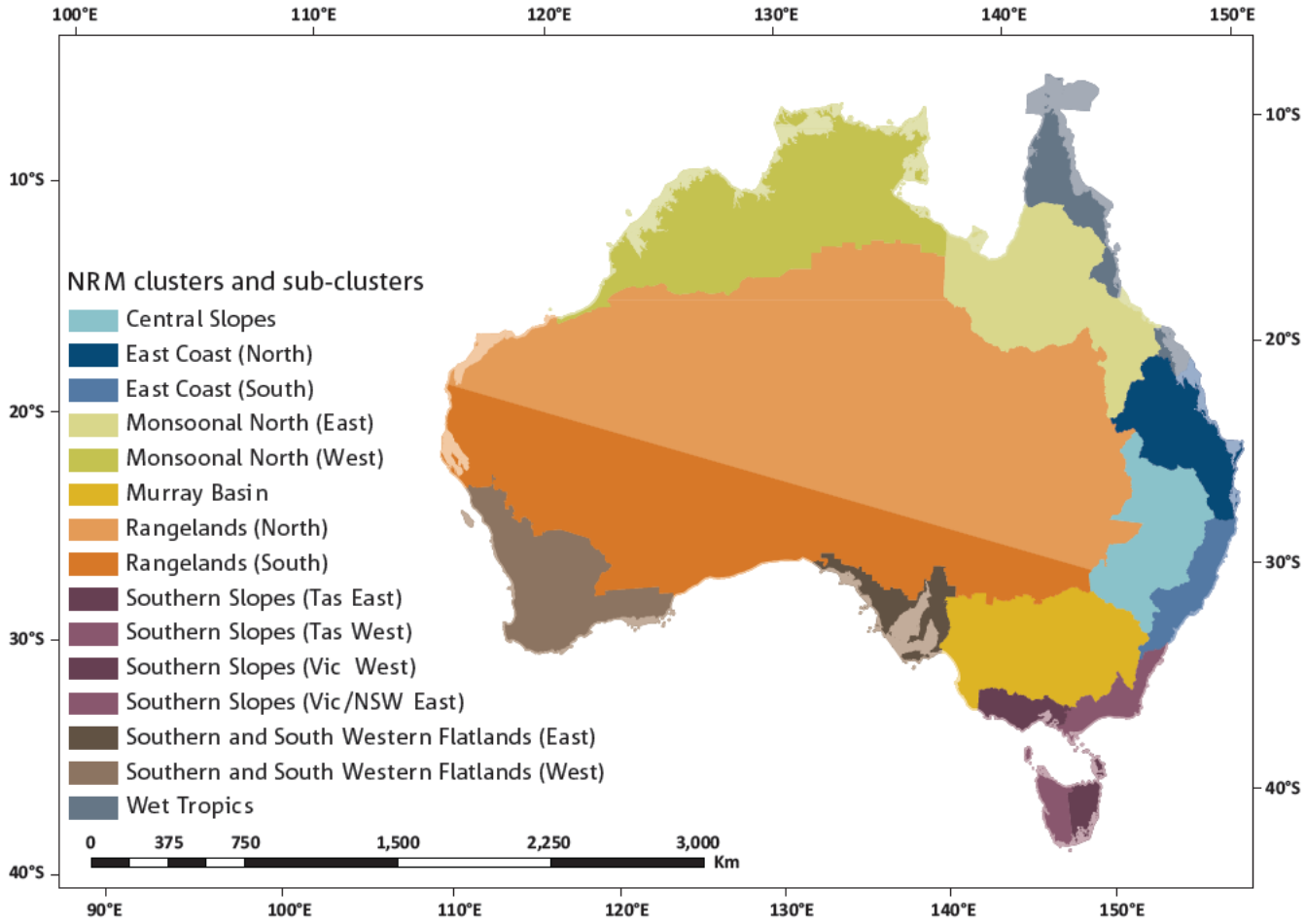


Figure 1.5. Map of Australia showing the natural resource management clusters (and sub-clusters) used in Australia's national climate projections. (Source: Climate Change in Australia)

1.4.4 Australia's national climate change projections

Australia's national climate change projections, Climate Change in Australia (CCIA), were released by the Bureau of Meteorology and CSIRO in 2015. They were developed through the Australian Government's Regional Natural Resource Management Planning for Climate Change Fund. As such, the CCIA projections are based on natural resource management (NRM) regions which have been grouped into eight clusters (Figure 1.5).

The Top End of the Northern Territory corresponds to the Monsoonal North (West) sub-cluster, while the central and southern parts of the Territory are covered by the Rangelands (North) sub-cluster.

This publication uses the CCIA projections unless otherwise noted.

Additional information can be found in the reports for the Monsoonal North (Moise et al. 2015) and Rangelands (Watterson et al. 2015) clusters, which are available along with other projections at www.climatechangeinaustralia.gov.au.

2. The Northern Territory's climate is changing

The Northern Territory's climate is shaped by weather systems and large-scale climate drivers that vary over space and time. This natural variability is now occurring against the backdrop of global climate change, and the climate of the Northern Territory is changing as a result. The extent of the changes to temperature, rainfall and other climate variables will depend on greenhouse gas concentrations in the atmosphere, with higher concentrations leading to larger changes.

2.1 What shapes the Northern Territory's climate?

The Territory's climate is shaped by a number of types of weather systems and large-scale drivers that operate over a range of time scales (Figure 2.1).

The **monsoon** is responsible for much of the wet season rainfall in the north of the Territory. Around late December each year the easterly trade winds reverse and become moisture-laden westerlies, signalling the monsoon onset (ESCC Hub n.d.). The monsoon persists until around April, going through a series of bursts (wet periods) and breaks (drier periods).

The timing and strength of the monsoon bursts are influenced by the **Madden-Julian Oscillation (MJO)**, a pulse of cloud and rainfall near the equator that recurs every 30–60 days. Monsoon bursts are more likely when the active phase of the MJO is near Australia and breaks are more likely when it is not (ESCC Hub n.d.). **Mid-latitude troughs** are also often associated with the timing of monsoon bursts.

The **El Niño Southern Oscillation (ENSO)** influences rainfall, temperatures and tropical cyclones. During the El Niño phase, there is reduced cloud cover leading to cooler minimum temperatures, reduced rainfall in the monsoon build-up and fewer tropical cyclones. El Niño years tend to have a later monsoon onset and lower rainfall totals overall. Dry season temperatures in the following year are generally higher. During the La Niña phase there are higher minimum temperatures in near-coastal areas due to higher sea surface temperatures, and increased rainfall in the build-up months. Dry season temperatures the following year are generally lower.

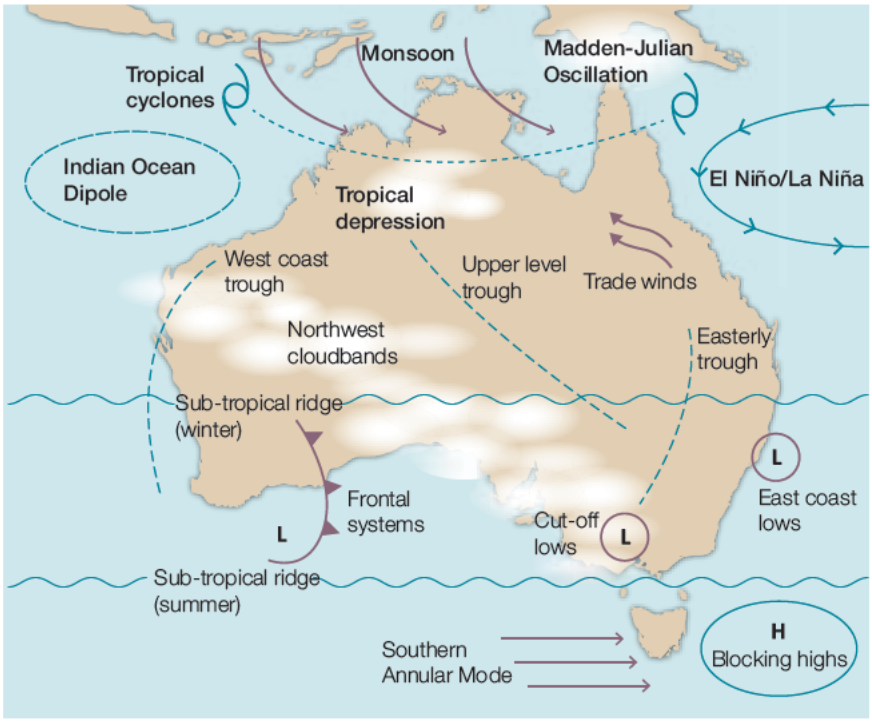


Figure 2.1. There are a number of weather systems and large-scale climate drivers than influence Australia's climate. Features in bold type particularly influence the Northern Territory.

The **Indian Ocean Dipole (IOD)** also influences rainfall and temperatures. In the positive phase of the IOD, the Top End experiences dry build-up months. The rangelands experience a dry winter-spring as well as higher maximum temperatures, due to the associated decrease in clouds and rain. In a negative IOD there is higher rainfall over the central Northern Territory in spring, and the increased cloud results in higher minimum temperatures. There is also higher rainfall in the north during the early wet season, and temperatures are warmer due to increased sea surface temperatures near Australia. The IOD may also be related to the monsoon onset (ESCC Hub n.d.).

These large-scale processes will change in a changing climate, although for some, such as the

monsoon, the changes are unclear (e.g. Narsey et al. 2020). For others, such as ENSO, we have a better idea of what the changes will look like. For example, El Niño events are projected to become more frequent and severe in the future (Wang et al. 2019). Extreme La Niña events are also projected to become more frequent (Cai et al. 2015). These changes will affect rainfall, drought and extreme climate events in the Territory.

Climate zones in the NT

Due to these large-scale influences and geography, the Northern Territory has three clear climate zones (Figure 2.2).

The tropical north experiences a hot, humid wet season from November to April and a cooler dry season from May to October. The central part of the Territory experiences hot, dry summers and mild winters. In the south, summers are also hot and dry, but winters can be cold.

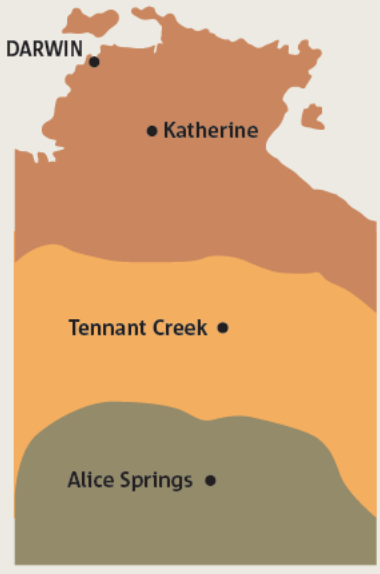


Figure 2.2. Northern Territory climate zones based on temperature and humidity (Source: Bureau of Meteorology)

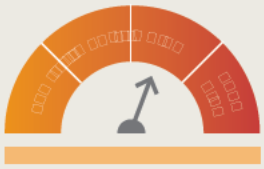
Interpreting climate change projections

The climate projections in this chapter are given for low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions pathways for the near future (2030), mid-century (2050) and end of the century (2090).

The projections are not for individual years in the future. Rather, they represent the 20- or 30-year period centred on 2030, 2050 and 2090 (the length of the period can differ between variables but is noted with each set of projections).

Many of the projections provide a change compared to a given baseline or reference period; for example, 0.14°C increase in average temperature compared to the average temperature for the period 1986–2005. Other projections have already applied the change to a historical value; for example, the projected number of extreme heat days has already added the number of additional days to the historical average.

Confidence ratings reflect how well we understand the physical processes for each variable and how well climate models can simulate them. If the confidence rating is high, then the projected range can be used as a good guide to potential climate change. If the confidence rating is low, then the results are plausible but other possibilities should also be considered possible. We have greater confidence in projections of some variables (e.g. temperature) than others (e.g. rainfall), and greater confidence in projections over large areas and long time periods (e.g. global climate change over a number of decades) than for smaller areas (e.g. regional and national projections) and short time periods (e.g. over periods of less than 10 years). The confidence meters in this report show you how much confidence we have in each of the projections for the Territory.





2.2 Temperature

2.2.1 Average temperature

In the north, average daily temperatures range from 15 to 33°C in the dry season (May to October) and 21 to 36°C in the wet season (November to April).

In the central region of the Northern Territory average daily summer temperatures range from 21 to 39°C, while winter is 6 to 24°C (Figure 2.3).

In the south, average daily temperatures range from 18 to 39°C in summer and 3 to 27°C in winter.

Since the middle of last century there has been a clear warming trend in the Territory, with many more hotter-than-average than cooler-than-average years (Figure 2.4).

People aged 40 who have spent their entire life in the Territory have only experienced nine cooler-than-average years in their lifetime. Seven-year-old Territorians have lived through five Australian prime ministers but no cooler-than-average years.

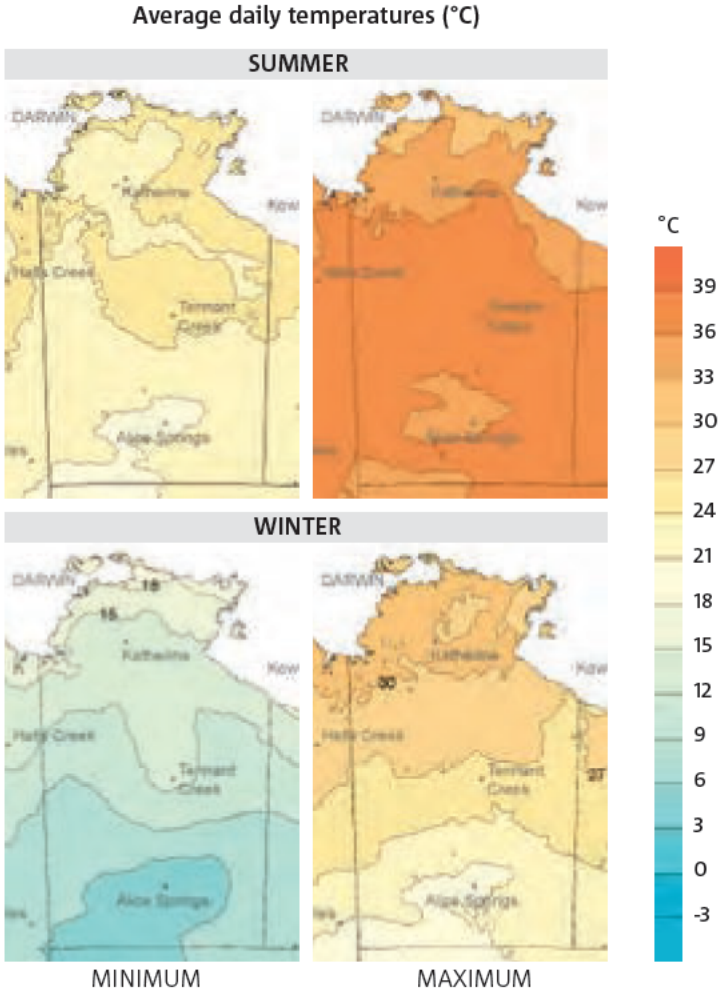


Figure 2.3. Average daily minimum and maximum temperatures for summer and winter in the Northern Territory over the period 1961 to 1990 (Source: Bureau of Meteorology).

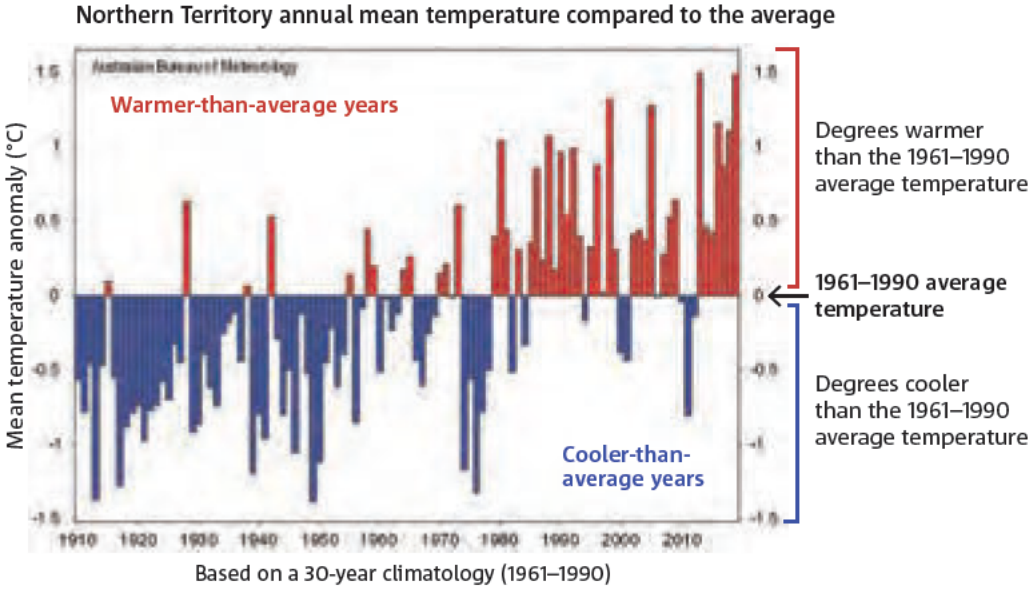


Figure 2.4. The Northern Territory's annual mean temperature difference from the 1961–1990 average for years from 1910 to 2019. Blue bars represent cooler-than-average years, while red bars are hotter-than-average-years.
(Source: Bureau of Meteorology)



The Northern Territory will continue to get warmer.

In the Top End, the near future (2030) will see warming around 0.5 to 1.4°C compared to the average for the period 1986–2005, with very little difference between emissions scenarios. By mid-century (2050), warming will range from 0.7 to 1.6°C under a low emissions pathway to 1.4 to 2.4°C under high emissions. At the end of the century (2090) warming will range from 0.6 to 1.8°C under low emissions to 2.8 to 5.1°C under a high emissions pathway.

Near future warming in the central and southern Territory is similar to the Top End at around 0.6 to 1.5°C, again with very little difference between emissions scenarios. Mid-century warming ranges from 0.7 to 1.6°C under low emissions to 1.4 to 2.4°C following a high emissions pathway. By the end of the century, the central and southern part of the Territory may experience warming of 3.1 to 5.6°C under a high emissions scenario.

How are we tracking?

Temperature observations have been tracking within the projected range to date (Figure 2.5), suggesting the projections are credible so far. We expect individual years to be cooler and hotter than this trend, which is also reflected in Figure 2.5.

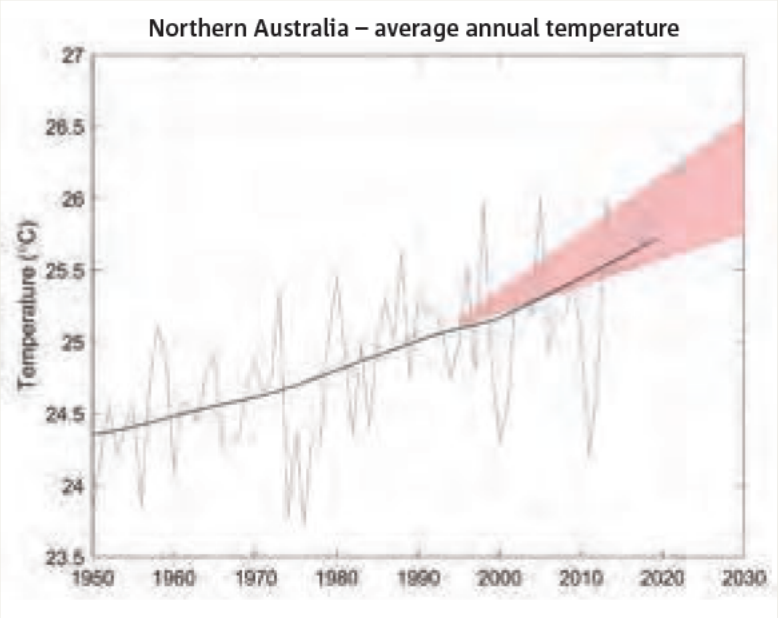


Figure 2.5. Average annual temperature in northern Australia as a whole (north of 26°S) for each year since 1950 (thin line) and the underlying trend (thick line) with the projected range of change for 1986–2005 to 2020–2039 under any emissions scenario from Climate Change in Australia added as a pink range. (The trend shows a 41-year lowess fit (Hawkins et al. 2020), observations are from ACORN-SATv2 dataset.)

Table 2.1. Annual mean temperature change for the near future, mid-century and end of the century under low, medium and high emissions pathways compared to the 1986–2005 average.

	Annual mean temperature change (°C) from 1986–2005 average								
	2030			2050			2090		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Top End Monsoonal North (West)	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (1.0 to 1.8)	1.8 (1.4 to 2.4)	1.0 (0.6 to 1.8)	1.8 (1.3 to 2.8)	3.7 (2.8 to 5.1)
Central and southern NT Rangelands (North)	1.0 (0.6 to 1.4)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.5)	1.2 (0.8 to 1.7)	1.5 (1.0 to 2.1)	2.1 (1.5 to 2.6)	1.1 (0.6 to 1.9)	2.1 (1.5 to 3.1)	4.4 (3.1 to 5.6)

A full table of projected changes in annual and seasonal minimum, maximum and average temperature is included in the appendix.

2.2.2 Extreme temperatures

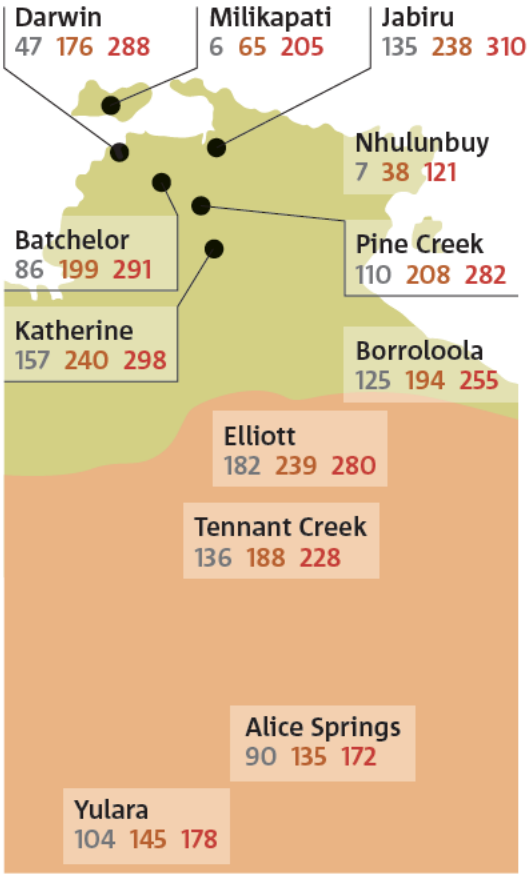
Extreme heat

Extreme temperatures are becoming more common in the Northern Territory (Figure 2.6, Table 2.1).



The hottest days in the Northern Territory will be hotter and more frequent, and warm spells will be longer.

By the middle of the century, the number of days a year over 35°C will at least double in many places across the Territory (Figure 2.7). The number of days over 40°C will also increase considerably.



Annual average number of days over 35°C under a high emissions pathway

Historical 1981–2010

Mid-century 2036–2065

End of the century 2075–2104

Figure 2.7. Projected number of annual average number of days over 35°C for the middle (orange) and end of the century (red) compared to the historical (grey) under a high-emissions (RCP8.5) pathway. Green shading indicates Monsoonal North projections region, orange is Rangelands.

A full table of projections for annual days over 35°C and 40°C for the 12 centres in Figure 2.7 is included in the appendix.

Table 2.2. Comparison of the average annual number of hot days in Darwin, Tennant Creek and Alice Springs between the periods 1959–1988 and 1989–2018 (BoM et al. 2019a, 2019b, 2019c)

	Darwin		Tennant Creek		Alice Springs	
	Days above 30°C	Days above 35°C	Days above 38°C	Days above 44°C	Days above 38°C	Days above 44°C
1959–1988	295	7	39	0	41	4
1989–2018	327	14	48	7	49	24

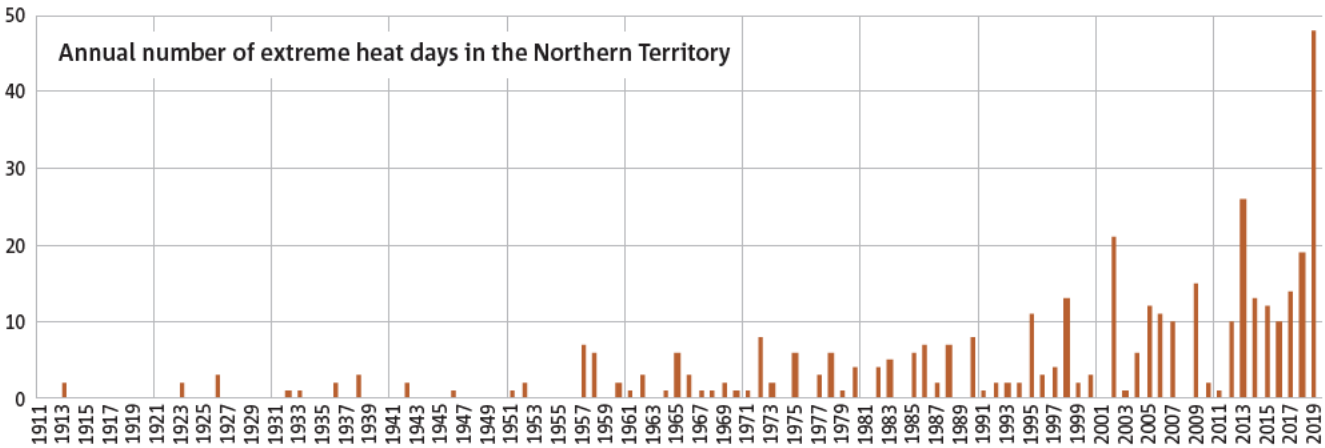


Figure 2.6. Number of days each year where NT area-averaged daily mean temperature is above the 99th percentile of each month (Data: Bureau of Meteorology)

Extreme cold

The southern part of the Territory can experience up to 40 potential frost days a year; however, the actual occurrence of frost depends on factors including temperature, humidity and cloud cover.

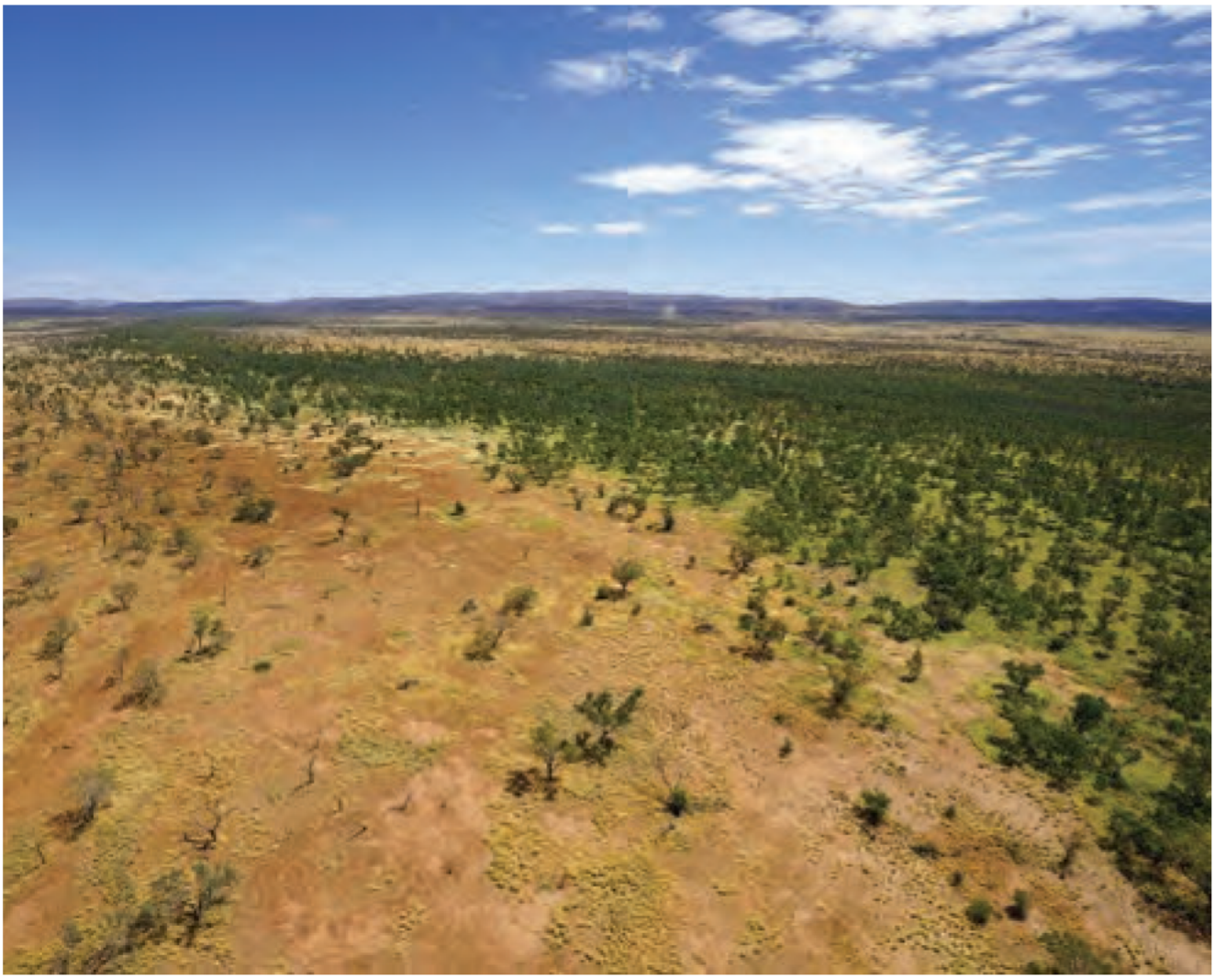
Frost risk days will decrease over time. For example, the number of frost risk days in Alice Springs will be halved by the middle of the century under the high emissions pathway.



Frost days will decrease.

Table 2.3. Projected annual number of days below 2°C.

ANNUAL DAYS BELOW 2°C	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Alice Springs	31	24	21	19	16	13	4
Yulara	24	15	13	11	9	7	1



2.3 Rainfall

2.3.1 Average rainfall

The Territory's Top End receives 600–1800 mm of rain in the wet season, but only 100–400 mm in the dry season (Figure 2.8).

Rain falls all year around in the central and southern parts of the Territory, but winter is the driest season with an average 50–100 mm rainfall in the central part of the Territory and 100–200 mm in the south. In summer, average daily rainfall in the central region is 400–900 mm and 200–400 mm in the south.

Rainfall can vary a great deal from year to year due to the normal variability of the climate system (Figure 2.9)

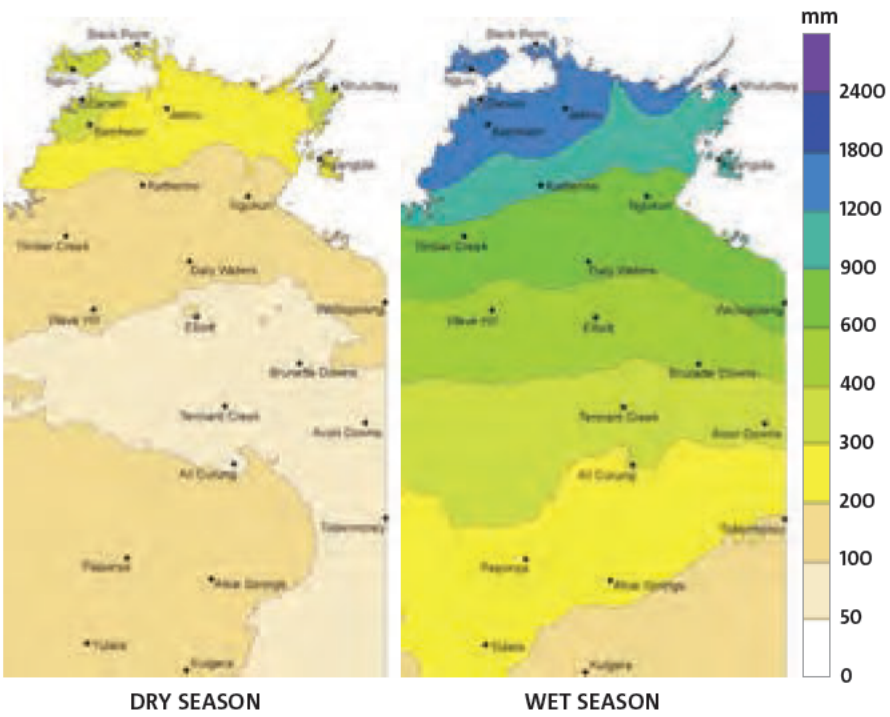


Figure 2.8. Average wet and dry season rainfall (mm) over the period 1961 to 1990 (Source: Bureau of Meteorology)

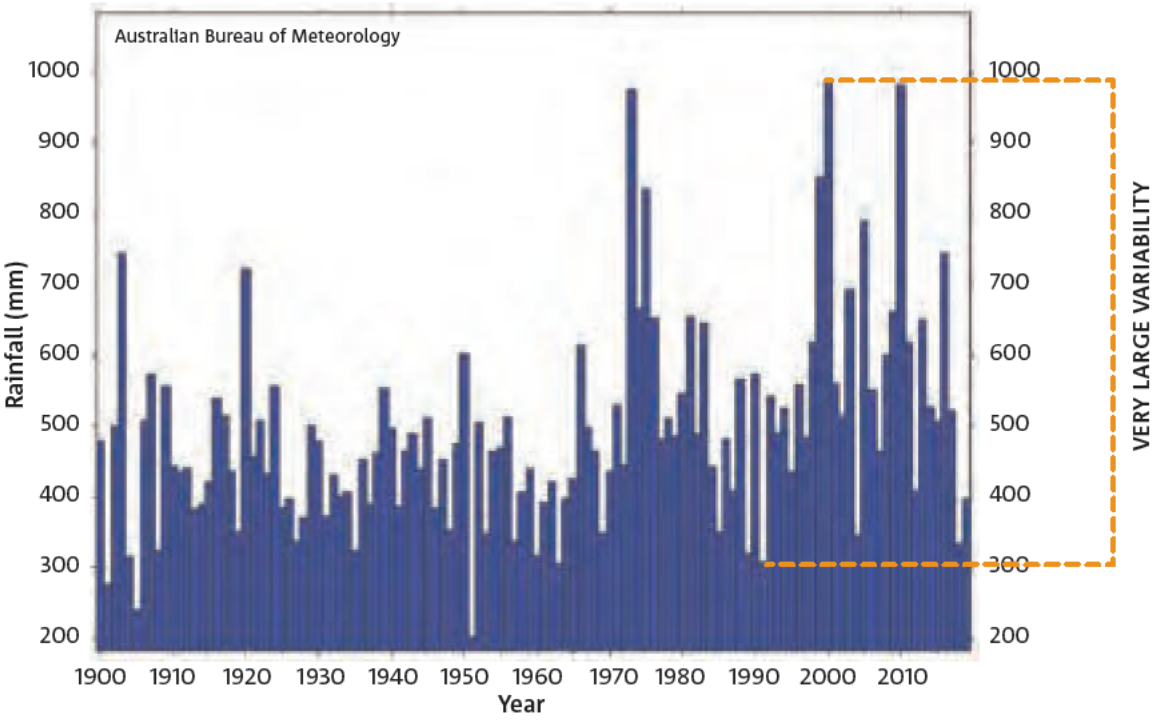


Figure 2.9. Total wet season rainfall (mm) for the period 1900/01 to 2019/20 showing the high year-to-year variability.

Over the past century, annual total rainfall has increased except for a small region in south-east Arnhem Land (Figure 2.10, left panel). More recently, drying in this region and further north on the coast has increased (Figure 2.10, right panel).

Comparing the 1959–1988 annual rainfall average with that for 1989–2018 indicates that annual rainfall has increased across the Northern Territory (Table 2.4).

There have also been changes in seasonal rainfall. Wet season rainfall has increased over the Top End, with Darwin recording a seasonal average of 1732 mm per annum for the period 1989–2018 compared to 1586 mm for the period 1959–1988 (BoM et al 2019a), and Tennant Creek recording an average of 459 mm and 343 mm per annum for the same periods, respectively (BoM et al 2019b). The annual average amount of rainfall at Alice Springs remained relatively unchanged between 1959–1988 and 1989–2018, although the seasonal distribution has changed, with more summer rainfall and less in March and the winter months (BoM et al 2019c).

In the near future, the effect of natural variability on rainfall is greater than the effect of climate change.

For the near future, natural variability will cause greater year-to-year changes in rainfall than the effects of climate change. In the Top End, near-future projections for the dry season range from 35% drier to 29% wetter than the 1986–2005 average, depending on greenhouse gas concentrations.

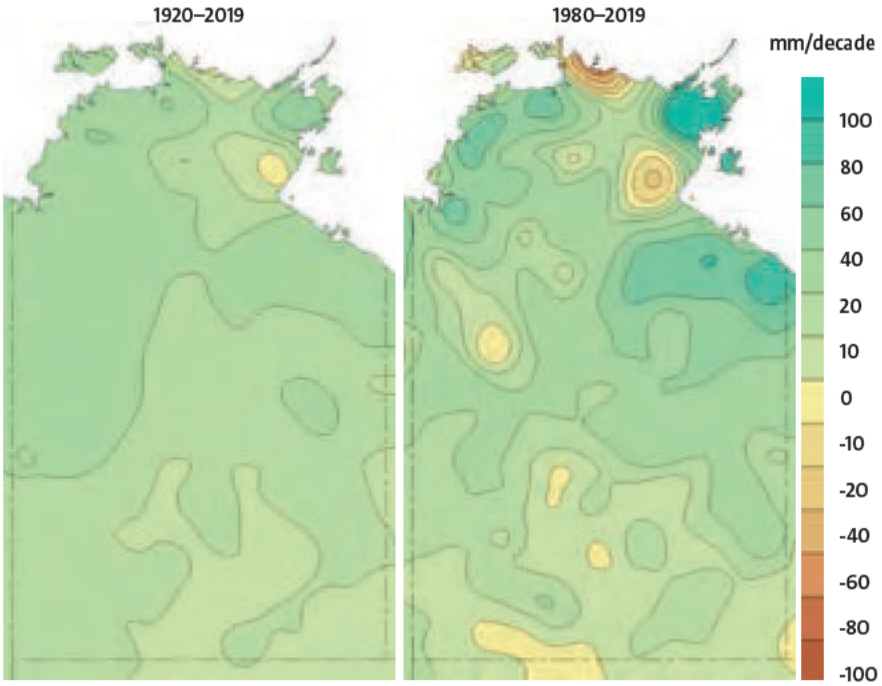


Figure 2.10. Long-term (1920–2019, left) and shorter-term (1980–2019, right) trends in annual total rainfall in the Northern Territory in mm per decade.

Projected wet season change for the same period ranges from 8% wetter to 7% drier. In the central and southern Northern Territory, annual rainfall change projections range from 12% drier to 8% wetter.



Later in the century, both wetter and drier futures are plausible depending on greenhouse gas concentrations.

Towards the end of the century, the projected dry season change in the Top End ranges from 45% drier to 44% wetter, depending on greenhouse gas concentrations. For the wet season, the range is 23% drier to 19% wetter. In the central and southern parts of the Territory, projected annual rainfall change ranges from 31% drier to 19% wetter, depending on greenhouse gas concentrations.

These large ranges and unclear direction mean that planning needs to consider both a drier and wetter future. A full table of projected changes in annual and seasonal average rainfall is included in the appendix.

How are we tracking?

The observed rainfall (dark line) has been tracking above the projected range, but within that expected from decadal variability, and has recently seen some drier years (Figure 2.11). The high variability makes it hard to assess if the projections are credible so far and we will need to wait for observations to 2030 to better assess the projection but so far, the observed trend is consistent with the projection.

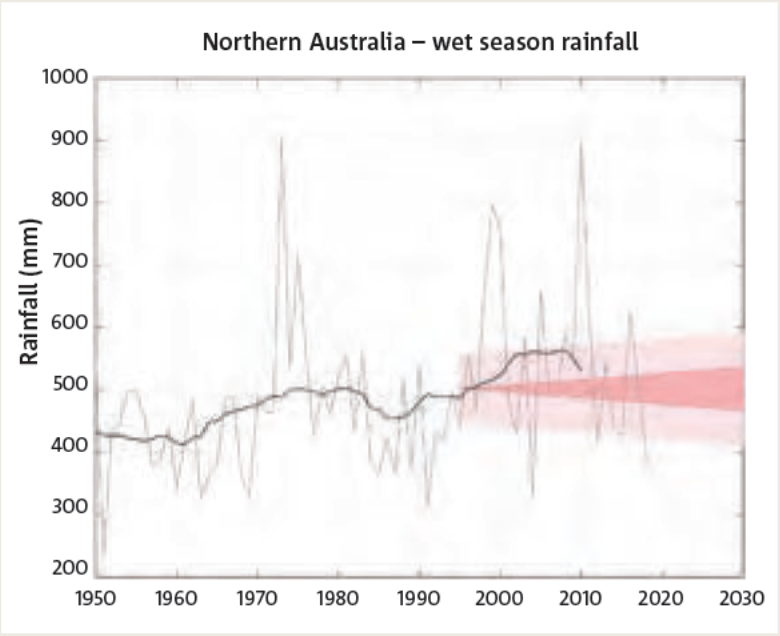


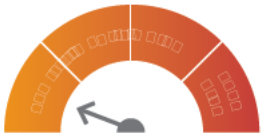
Figure 2.11. Total wet season rainfall in northern Australia as a whole (north of 26°S) for each year since 1950 (thin line) and the underlying trend (thick line) with the projected range of change for 1986–2005 to 2020–2039 under any emissions scenario from Climate Change in Australia added as a pink range. The decadal variability is shown as a feint pink band. (The trend uses a 20-year moving average (Hawkins et al. 2020), observations are from AWAP.)

2.3.2 Extreme rainfall

Extreme rainfall in the Northern Territory often results from tropical cyclones, tropical lows and long-lived thunderstorms.



Heavy rainfall events will become more intense.



How much more intense is not clear.

As the air becomes warmer it has a greater capacity to hold water vapour. This means that, even though changes to average rainfall are unclear, the intensity of heavy rainfall events will likely increase in the future across the Territory.

2.3.3 Drought

From the Federation Drought at the turn of the 20th century through to the recent 2017–2020 drought, Territorians have experienced a number of periods of extended, unusually dry conditions. Drought occurs all over the Territory; however, the south is typically more prone to drought than the north.

Impacts of drought are likely to be more severe in the future due to increasing temperatures. However, changes in drought are unclear in climate models, given the relationship to rainfall. We have low confidence in projecting how the frequency and duration of extreme meteorological drought may change, although under a high emissions pathway the time spent in drought will increase by 2090 in the central and southern parts of the Territory.



Frequency and intensity of droughts will change.



Time spent in drought will increase.



2.4 Tropical cyclones

Tropical cyclones can occur in the Northern Territory between November and April. The Northern Territory is in Australia's Northern tropical cyclone region, which covers the Territory and extends west to the north-eastern Kimberley and east to the Queensland Gulf coast. On average, there are three tropical cyclones each season in this region (BoM 2019).

Tropical cyclones contribute up to 12% of rainfall along the coastal region of the Territory during the tropical cyclone season (Dare et al. 2012). Contributions to inland rainfall get progressively smaller as you move further south. The frequency of tropical cyclones varies considerably from year to year due to the influence of large-scale climate drivers (see Section 2.2).

The number of tropical cyclones across the Australian region has been declining since formal records began; however, over the Northern Territory there has been no discernible trend (Chand et al. 2019).



Tropical cyclones will become less frequent but more intense.

Tropical cyclones are projected to become less frequent but with more energy in the climate system from warming, they are likely to be more intense.

There is some potential that tropical cyclones may also reach slightly further south under a warmer climate, associated with warmer oceans and changing large-scale wind patterns. However, there is relatively low confidence in regional aspects of these projections due to challenges associated with modelling tropical cyclones, including their frequency, intensity, formation and tracks (ESCC Hub 2019a).

Rainfall produced by tropical cyclones is also expected to increase, particularly the intensity of extreme rainfall events which could increase by about 10% or more per degree of global warming (noting that about one degree of warming has already occurred). This is because a warmer atmosphere can hold more moisture, as well as increase the energy available for cyclones (ESCC Hub 2019a).

When this increased rainfall intensity is combined with higher sea levels (see Section 4.7.1), it is likely that flooding will increase in frequency and magnitude in the future for many coastal and estuarine regions.



2.5 Fire weather

Bushfire occurrence relies on having an ignition source, fuel availability, fuel dryness and suitable fire weather (hot, dry, windy). In the Northern Territory fuel availability is a major limiting factor. This depends largely on rainfall.

In the central and southern regions of the Territory, conditions are most conducive to bushfires in spring (September–November). In the north, the most dangerous fire weather conditions occur in the dry season. This is when conditions are drier and there is increased fuel availability following the wet season. Over the past 30 years or so, the number of days with severe fire weather has increased during the dry season (winter and spring) (ESCC Hub 2019b; Figure 2.12).



Fire weather will become more frequent and harsher.

In the Top End, where abundant rainfall and bushfires are common, there is projected to be little change to fire frequency.

In the southern and central parts of the Territory, changes to fire frequency depend on rainfall changes. With higher temperatures and lower rainfall, climate change will result in a harsher fire-weather climate in the future; that is, when bushfires occur, more extreme fire behaviour can be expected.

The national projections for fire weather are based on a Forest Fire Danger Index. Given the relatively low proportion of forested areas in the Northern Territory, this measure is not as accurate as in other states but can still be used as a useful indicator of possible fire weather changes.

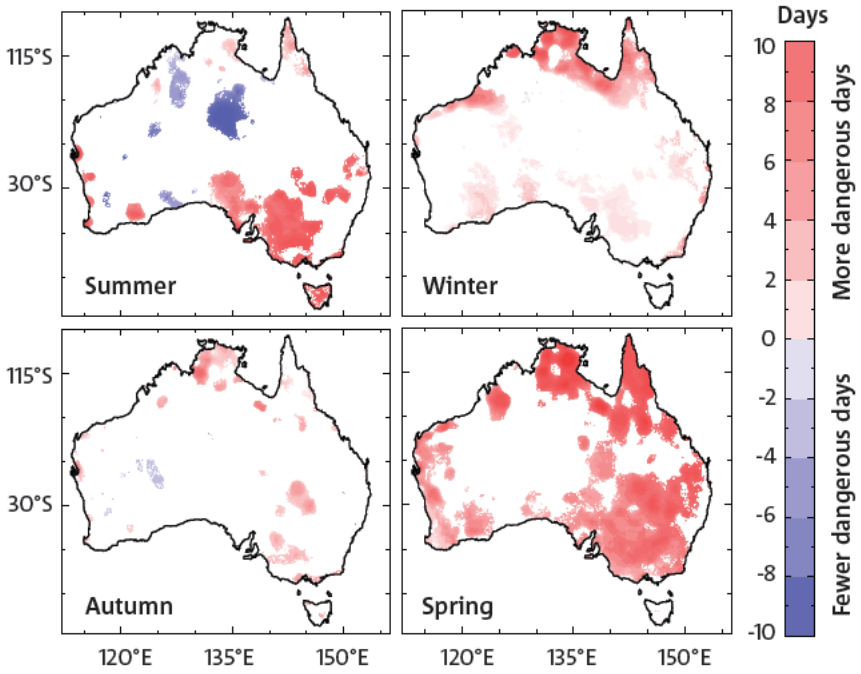


Figure 2.12. The number of fire weather days in the period 2000–2016 compared with 1983–1999. Dangerous days are those where the Forest Fire Danger Index (FFDI) is greater than the 90th percentile at a given location. (Source: ESCC 2019b)



2.6 Evaporation

While evaporation rates have largely remained unchanged in the Top End (BoM et al. 2019a), in the central part of the Territory they have decreased. At Tennant Creek over the past 30 years (1989–2018) there has been a decrease in potential evaporation of about 5–10 mm in each of the cooler months (June through August), and of more than 20 mm in the warmer months compared with the previous 30 years (1959–1988) (BoM et al. 2019b). In the southern part of the Territory, spring and autumn potential evaporation rates at Alice Springs have increased by 10–20 mm for each month in the past 30 years (1989–2018) when compared to the previous 30 years (1959–1988). In other months, potential evaporation has increased by less than 10 mm each month (BoM et al. 2019c). Understanding changes in evaporation is important for planning how much water our agricultural industries will need.

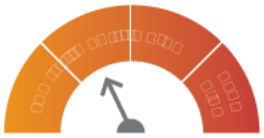
Estimating evaporation

Measures of evaporation may use one or more of a number of terms to describe what is being measured. Actual evaporation is difficult to measure, so potential evaporation is generally used instead. Potential evaporation is the maximum possible evaporation rate under given meteorological conditions if water is available. Measuring potential evaporation over a large region is not practical, so it is estimated by pan evaporation, which is a measure of potential evaporation over a small body of open water (like a pool or 'pan').

The terms evaporation and evapotranspiration are also used, sometimes interchangeably; however, evaporation refers to the transfer of water from the land surface to the atmosphere while evapotranspiration also includes transfer via vegetation.



Potential evaporation will increase.



The size of the increase is less clear.

Across the Territory projections for potential evapotranspiration indicate increases in all seasons, with the largest absolute rates in summer by 2090.

A full table of projected changes in annual and seasonal average evapotranspiration is included in the appendix.



2.7 Humidity

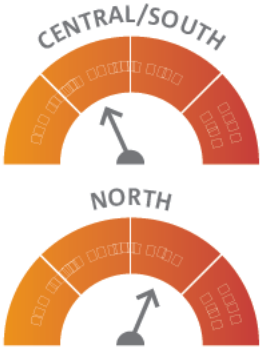
Relative humidity is the amount of moisture in the air as a percentage of the total amount of moisture the air can hold. For example, 50% relative humidity means the air is holding half the moisture it could possibly hold. Relative humidity depends on temperature: cooler air does not hold as much moisture as warmer air. This means that for any specific amount of moisture, the relative humidity will be higher at cooler temperatures – which is why Alice Springs has high relative humidity in winter months (Figure 2.13).

In the near future there is little change projected in relative humidity across the Territory.

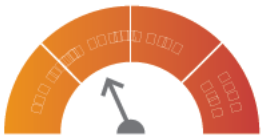
By the end of the century, under a high emissions pathway, relative humidity is projected to decrease in the Top End.

In the central and southern parts of the Territory a decrease in relative humidity is projected in summer and autumn. Projections for a decrease in winter and spring (up to 5% under medium emissions and 10% under high emissions) have high confidence.

A full table of projected changes in annual and seasonal average relative humidity is included in the appendix.



In the near future we expect little change in relative humidity across the Territory.



At the end of the century, relative humidity will decrease across the Territory.

Along with temperature and wind speed, relative humidity determines how cold or hot it actually feels. This is often reported as 'apparent' or 'feels like' temperature - although in the NT it could be called 'How sticky is it today?'

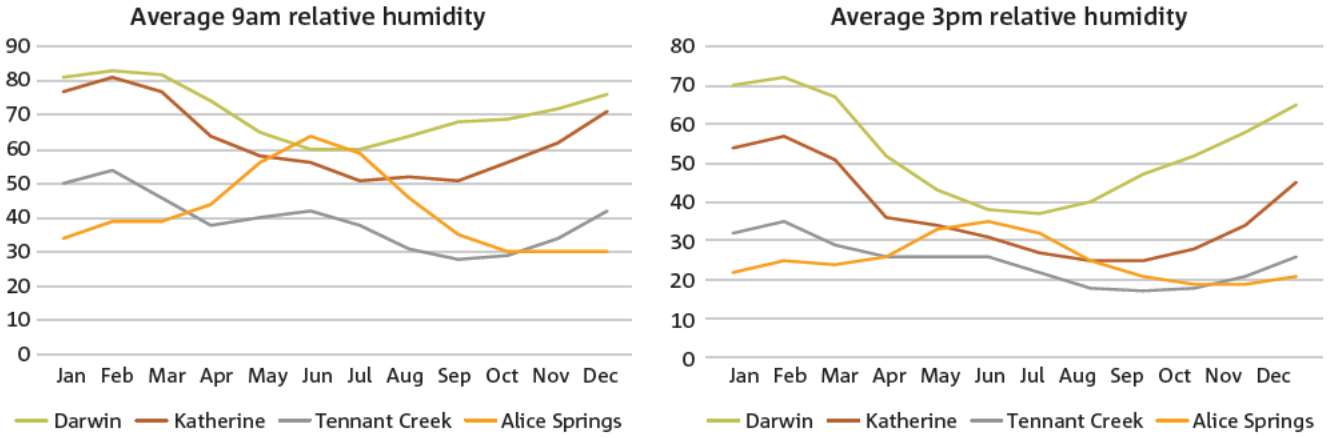


Figure 2.13. Average monthly relative humidity at 9 am (left) and 3 pm (right) for Darwin (Darwin Airport, station 014015; 1954–2010), Katherine (Katherine Council, station 014902; 1957–2010 9 am, 1957–1985 3 pm), Tennant Creek (Tennant Creek Airport, station 015135; 1969–2010) and Alice Springs (Alice Springs Airport, station 015590; 1954–2014). Data from Bureau of Meteorology.

2.8 Coasts and oceans

2.8.1 Mean sea level

Global warming is causing sea levels to rise in two ways. The first is through thermal expansion – as water warms, its volume increases (so it takes up more space). This accounts for around one-third of the rise we have seen to date (CSIRO and BoM 2018). The remainder is from melting ice sheets and glaciers that are adding more water to the oceans.

Melting ice and snow on land increase sea level because this adds water to the oceans, but melting sea ice does not increase sea level because it's water already in the ocean. It's just the same as when ice floating in your drink doesn't cause it to overflow as it melts in the Territory heat!

Sea levels have risen around Australia

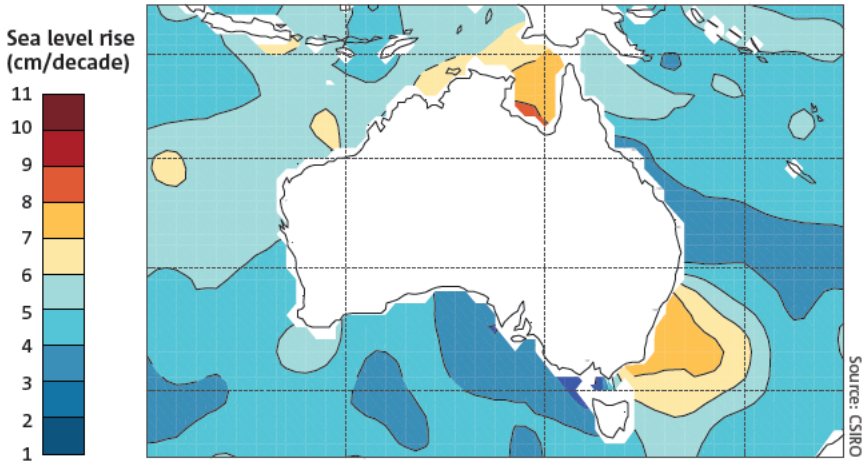


Figure 2.14. The rate of sea-level rise around Australia based on satellite observations for 1993–2017. (Source: CSIRO and BoM 2018)



Sea level rise is not uniform. Changes occur at many time scales (from hours to decades) due to factors including tides, storm surges, seasonal changes and the influence of climate drivers like El Niño and La Niña (CSIRO 2020).

The sea level around the Northern Territory coastline has risen at a higher rate than much of the rest of the country due to the combination of natural climate variability and climate change (White et al. 2014) (see Figure 2.14).

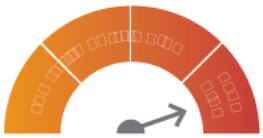


Mean sea level will continue to rise.

In the near future, the projected increase is 0.06 to 0.17 m above the 1986–2005 level, with only minor differences between the different emissions pathways. As the century progresses, the differences between the pathways become more pronounced. At the end of the century, a medium emissions pathway gives a rise of 0.28 to 0.64 m while a high emissions pathway gives a rise of 0.38 to 0.85 m (Figure 12.15).

2.8.2 Extreme sea level events

Tides, winds and severe weather systems can cause extreme sea-level events. In the Northern Territory, tropical cyclones cause extreme storm surges.



The height of extreme sea levels will increase.

Rising sea levels will exacerbate the impacts of storm surges and other extreme sea-level events.

Projected sea-level rise under a high emissions pathway for coastal local government areas

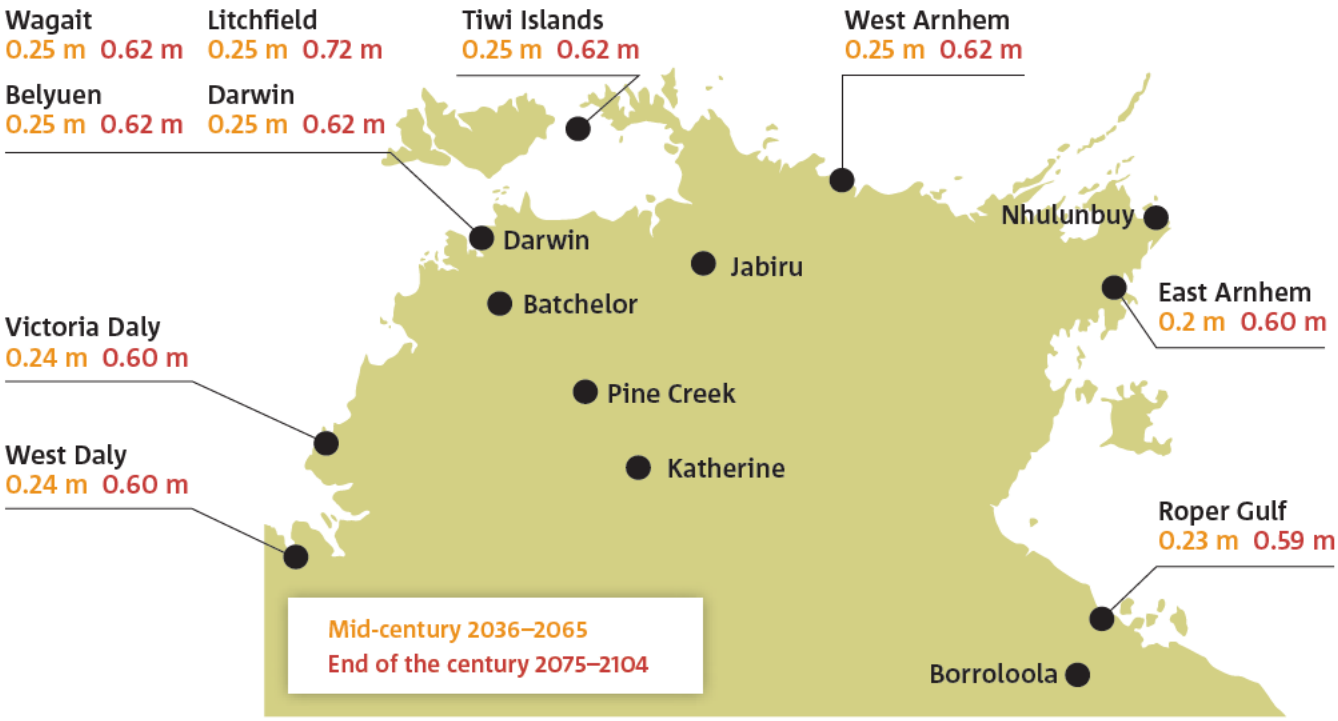


Figure 2.15. Mean projected sea-level rise for the middle (2050, orange) and end of the century (2090, red) for Northern Territory coastal local government areas under a high-emissions (RCP8.5) pathway.

A full table of sea-level rise projections for Northern Territory coastal local government areas is included in the appendix. The table also includes allowances, which are the minimum distances required to raise an asset to maintain current frequency of breaches under projected sea-level rise.

2.8.3 Sea surface temperature

Sea surface temperature has risen significantly across the globe over recent decades. Sea surface temperature around the Northern Territory has warmed by at least 0.5°C since 1950 (Figure 12.16).



Sea surface temperature will continue to increase.

In the near future, sea surface temperature at Darwin is projected to increase by 0.4 to 1.1°C. At the end of the century warming across the Northern Territory's coastal waters is projected to be from 0.3 to 1.6°C under a low emissions pathway up to 2.2 to 4.1°C under a high emissions pathway.

2.8.4 Marine heatwaves

In the same way that heatwaves are extended periods of high temperature on land, extended periods of high sea surface temperatures are known as marine heatwaves.

Globally, marine heatwaves are becoming longer and more frequent: between 1925–1954 and 1987–2016 the number of marine heatwave days averaged across all the oceans increased by 50%. They are also becoming more intense (Oliver et al. 2018a).

The 2015/16 northern Australian marine heatwave persisted for 224 days – the longest in the region on the satellite record – with the temperature rising to 1.6°C above average. The changing climate has been shown to have increased the likelihood of this event occurring (Oliver et al. 2018b).

The number and intensity of marine heatwave days will increase.

The number of marine heatwave days per year and the intensity of marine heatwaves is projected to increase across the 21st century, with the degree dependent on greenhouse gas emissions. Under a high emissions pathway, the intensity of marine heatwaves could be double that of under a medium emissions pathway (Oliver et al. 2019).

2.8.5 Ocean chemistry

Around one-third of the carbon dioxide emitted into the atmosphere by humans over the past 200 years has been absorbed by the oceans. This has led to a 0.1 pH fall in the ocean's surface water pH (a 26% rise in acidity).

The ocean surface around Australia has warmed, especially to the southeast

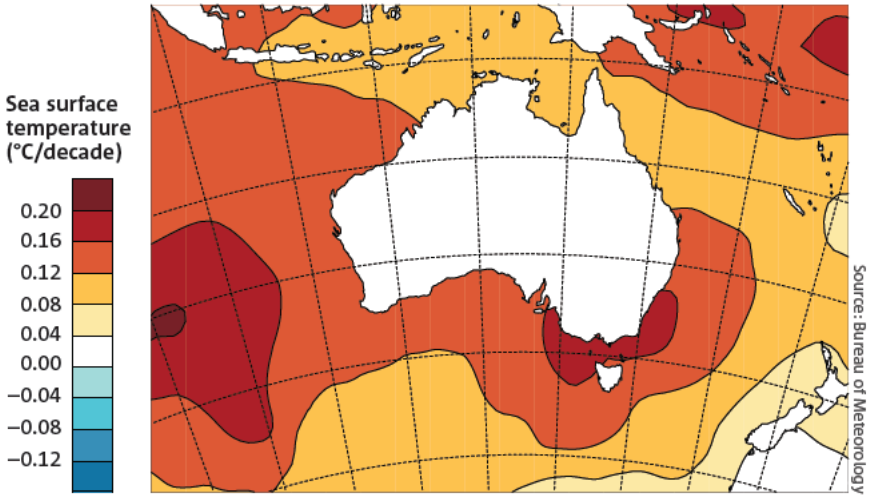


Figure 12.16. Trends in sea surface temperatures in the Australian region from 1950 to 2017. (Source: CSIRO and BoM 2018)



The ocean around Australia will become more acidic at a rate proportional to carbon dioxide concentrations in the atmosphere.

In the near future, pH is projected to fall by an additional 0.07 units in the Northern Territory's coastal waters. At the end of the century, decreases of up to 0.14 (under medium emissions) and 0.3 (under high emissions) are projected. These values represent a 40 and 100% increase in acidity respectively.

pH

Acidity is measured using the pH scale, which ranges from 0 to 14, where 0 is most acidic and 14 is most alkaline (or basic). A pH of 7 is neutral. The scale is logarithmic which means each whole number value below 7 is 10 times more acidic than the previous value. This is why small changes in pH (e.g. 0.1) are big changes in acidity (26%).



3. Impacts on the Territory

Our environment, communities and economy are all vulnerable to the changing climate. Many aspects of Territory life are already being impacted. Identifying and understanding these impacts is critical for planning for the future – to reduce the risk of ongoing or more severe impacts and to identify opportunities for Territorians to build more resilient communities, develop a sustainable economy and maintain healthy natural systems.

3.1 Community/ environment

3.1.1 Human health

Climate change will have both direct impacts on human health as well as other impacts that may not be immediately recognised. Some groups are likely to be more susceptible to climate change, such as young children, older people, people with existing chronic illnesses, the socially isolated or disadvantaged, outdoor/ manual workers, very low-income workers, women seeking shelter, people in communities dependent on agriculture and land and Aboriginal Territorians (Coast Adapt 2017).



- Extreme weather events could result in injuries and death.
- Increased temperatures and extreme heat days will result in heat stress and dehydration.
- Heat stress can exacerbate cardiovascular, renal and other chronic diseases.
- Floods (and humidity) favour vector-borne diseases (malaria, dengue, other fevers), melioidosis, leptospirosis which can result in death.
- Displacement of livelihoods could lead to stress, anxiety and other mental health problems.
- Bushfire smoke could lead to respiratory problems.
- Extreme weather and flooding can disrupt transport networks, impacting on food availability and security, as well as provision of health and support services.

Treatment of kidney disease

The best treatment option available for patients with advanced kidney disease is haemodialysis. It can be accessed at home or in communities, but it requires a reliable and high-quality water supply. Each dialysis treatment requires 600 litres of water and patients dialyse three times per week for up to seven years. An estimated 31.1 megalitres of water was required in both the Top End and Central Australia for haemodialysis treatments in 2018–19. Projections indicate that haemodialysis water use will more than double to 81.5 megalitres by 2036. Water scarcity is likely to force the majority of clients to undergo their treatment in major urban settings, reducing their ability to have community-based dialysis, dislocating them from their land and culture, and potentially increasing urban water security challenges.

3.1.2 Coasts and marine resources

The vulnerability of our coastal areas to sea level rise is influenced by a variety of factors such as human activities, nature of coastal processes, geographic location, and type of land cover. The impacts of sea level rise will be felt most acutely from the combination of extreme events – such as high tides, surface waves, storm surge and flooding rivers – which are becoming more intense and frequent (Pathirana and Baban 2008).



- Rising sea levels and storm surges will impact coastal communities and infrastructure (roads, jetties, marinas, landings and boat ramps as well as homelands and outstations), cultural artefacts and sacred sites, and has the potential to contaminate groundwater sources.
- Flooding compromises infrastructure (i.e. residential and commercial structures, public infrastructure) from pressure forces and floodwater.
- Building materials may decay after contact with floodwaters which are accelerated from contaminants (e.g. sewage, petrol and chemicals).
- Floating debris can also cause additional damage or pressure, and the force of floodwaters can cause erosion and collapse of soils supporting a structure (Mason et al 2010; NCCARF 2016).
- Infrastructure such as roads, culverts and bridges can be severely impacted by floodwaters.
- Erosion can undermine foundations and impact infrastructure in close proximity to coastal and estuarine foreshores (NCCARF 2016; Woodroffe et al 2010).

Seagrass

Rising water levels mean that seagrass will get less light and intertidal meadows will have more exposure to daylight during low tides. This will reduce the area they can survive in, which will in turn affect the number of dugongs, as they rely solely on seagrass for food. This will reduce the number of dugongs in our waters, and impact on cultural and resources values for Aboriginal communities across the Top End.

3.1.3 Water supply

Climate change impacts rainfall, underground water reserves, surface water flows, and changes how humans use water. How these impacts play out across the Territory will be region and ecosystem specific and cannot be generalised for the whole of the Northern Territory.



- Water supply and quality can be affected by damage and disruptions in long-lived constructed civil, mechanical and electrical assets such as dams, pipelines, treatment plants and pumping stations.
- Higher intensity rainfall events will test the capacity of stormwater systems, treatment plants and sewerage networks.
- Extended periods of hot, dry weather can lead to pipes cracking as a result of changes in soil moisture or temperature, or as tree roots spread to source water.
- Sea level rise, storm surge and flooding are likely to affect water and wastewater infrastructure and can result in water contamination issues which impact public health and the environment (National Water Commission 2012; Infrastructure Australia 2017, 2019).

3.1.4 Biodiversity and ecosystems

The identity and lifestyle of most Territorians are integrated with the Territory's biodiversity and ecosystems through both employment and leisure. For Aboriginal people, who managed and originally shaped this landscape, connections with the natural world are deeply spiritual, and reflected in an intricate belief system with resounding expression in ancient art forms. We want to ensure that the biological diversity and integrity of the Territory's natural heritage remains intact both now and for future generations.

The way that climate change impacts the natural environment of the Northern Territory will vary between regions, ecosystems and species.



- Rising temperatures and sea levels, as well as climate-induced changes in fire regimes, and extreme weather events will intensify existing threats such as habitat loss, invasive species and drought.
- Marine heatwaves can cause coral bleaching, which can damage the integrity of reefs and reef ecosystems.
- Increasing sea and air temperatures could change species ranges and timing of life cycle stages.

Gulf of Carpentaria mangroves

Climate change is likely to damage key natural systems, as evidenced by the mangrove dieback in late 2015 in the Gulf of Carpentaria. The coincidence of unusually hot and dry conditions with unusually low sea level likely provided a stressful environment for the mangroves. This cumulative stress during most of 2015 almost certainly contributed to the major dieback near the end of the year (Harris et al. 2017)

3.2 Economic sectors/assets

3.2.1 Agribusiness

Agribusiness encompasses all forms of agriculture undertaken in the Northern Territory including the production of all types of livestock, crops, seafood (wild caught and/or farmed) and bush foods (collected and sold on a commercial basis).

In 2017-18, agribusiness contributed approximately 2.8% (or $735 million) to the Northern Territory's GSP and employed an estimated 4.1% of the Northern Territory workforce (or 1743 jobs).

Disruption to the agribusiness sector will have a flow-on impact to Territory-based suppliers supporting the sector – including specialist heavy vehicle transport providers and businesses providing the inputs such as agrichemicals, farm machinery, fencing, irrigation equipment and seeds.



- Current breeds may not tolerate the changes in climate such as an increase in extreme heat days.
- Heat stress could decrease productivity through reduced feed intake.
- Increased temperatures lead to higher water demand by grazing animals and this tends to lower the range from which the animals will travel from their water source. This limits the use of the available grazing resources and increases the pressure placed on pastures adjacent to water sources and lifts the risk of soil degradation.
- Increased variability of the Top End's wet season will periodically reduce the level of feed available for cattle and increase the potential for bushfires to further reduce the available pasture as well as cause additional damage to fences and other infrastructure.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost to manage these impacts.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.



- A drier climate with more intense rainfall events increases risks from runoff leading to erosion and loss of topsoil.
- Current varieties may not tolerate the changes in climate such as an increase in extreme heat days.
- Exposure to increases in the length and severity of heat waves and an increase in the number and severity of extreme weather events may impact on horticultural production in the Territory.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost of inputs.
- Forestry plantations on the Tiwi Islands and in the Douglas Daly region are likely to be at greater risk of fire damage.
- Sea level rise can lead to increased saltwater intrusion and tree dieback in coastal and floodplain properties and potential changes to aquifer water quality.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.



- Rising sea temperatures and sea levels may change fish and prawn distribution and abundance and the range of coastal areas available for aquaculture.
- With more variability in the reliability of the Top End's wet season, reduced run-off in the creeks and rivers in some years is expected to impact on the availability of key fish species.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost of inputs.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.

Mango production

Mango production is sensitive to temperature change as flowering is promoted by low night temperatures and can be inhibited by high day time temperatures. In the future, some commercially important varieties may no longer be suitable for where they are currently growing. Mango growers will need to consider a range of adaptation options to ensure the ongoing sustainability of their businesses (Clonan et al. 2020).

3.2.2 Infrastructure (construction)

The Northern Territory's construction industry employs more than 10,000 people – 7.8% of the Territory's workforce. In 2018–19, the industry contributed $1.6 billion to the Northern Territory economy (Northern Territory Government n.d.).



- Climate change will significantly impact infrastructure in multiple direct and indirect ways. The vulnerability of infrastructure is determined by the degree of climate change to which it is exposed and also how we respond in the design of our infrastructure: how and where we build new structures; how we adapt existing ones and how we modify our infrastructure use (The Climate Institute 2012).
- Direct physical risks include weather or temperature related events such as floods, rising sea levels and more intense natural disasters.
- Indirect risks to infrastructure from climate change include the changes in financial systems, for example, the availability of funding and insurance for infrastructure projects and the behavioural changes brought about by adapting to climate change.
- In the construction industry, climate change may change access to worksites, conditions for workers, and building standards.

4.2.3 Energy and minerals

The mining, manufacturing and energy sectors (including natural gas and LNG) accounted for 22.7% (or $5.74 billion) of economic output and employed approximately 5.2% of the Northern Territory workforce in 2018-19 (Northern Territory Government n.d.).



- More frequent and intense natural disasters can damage mines, transportation and energy infrastructure and equipment. The damage caused may in turn disrupt construction and operations.
- Heavy rain and increased erosion may affect slope stability for open-cut mines and their related mullock heaps.
- Flooding from increased rainfall in some areas can interrupt production and may necessitate additional controls to enhance water treatment capacity.
- Heavy rainfall is likely to disrupt land transportation routes and degrade roads.
- Increasing temperatures, greater precipitation, shifting storm patterns, and rising sea level may impact the transportation services that supply goods and services, carry personnel and move ore to facilities for processing and to ports for export.
- Disruption in delivery of input materials or consumables such as diesel, tyres, and reagents, will curtail production or limit its efficiency.
- Rising sea level may make coastal facilities harder to access and major cyclones will affect port availability, interfering with timely transport to market.
- Hotter and drier conditions may increase wildfires that threaten facilities.
- Increased water scarcity in some locations will inhibit water-dependent operations and complicate site rehabilitation.
- Heavier rainfall could result in tailings dam failure, discharge of contaminated water into surrounding areas, accompanying remediation costs and increases in environmental liability.
- Natural disasters pose immediate health and safety risks, while warmer temperatures may affect worker recruitment, retention, safety and productivity.

3.2.4 Defence and defence support initiatives

The Northern Territory is strategically important for the Australian Defence Force (ADF) and this is reflected in the key role the ADF plays in the Northern Territory economy. The ADF contributes approximately $1.9 billion to the Northern Territory economy annually through direct and indirect employment of Territorians, demand for goods and services, exercises held and infrastructure projects. There are approximately 12,000 ADF personnel and their families based in the Northern Territory, which is 8.1% of the ADF population.



- Increases in heatwaves and heat stress in the wet season may limit outdoor activities by ADF personnel.
- General climate change impacts could contribute to an increase in political and military conflict in Asia which could impact northern Australia, resulting in internal and external migrations in the region and the need for additional infrastructure and industrial capacity to support the Australian Defence Force and its visiting forces.

Disaster and humanitarian support

The Northern Territory is one of the key deployment points for disaster and humanitarian assistance in the region with the National Critical Care and Trauma Response Centre located in Darwin. The Australian Defence Force has been deployed from the Territory on several occasions to provide logistical, environmental and medical support. As multiple disaster events increase in severity and frequency, there will be increasing pressure on the Northern Territory's existing capacity to appropriately respond to these events.

3.2.5 Tourism

The Northern Territory's tourism is driven in part by some of Australia's most iconic nature-based tourist attractions, including Garig Gunak Barlu (Cobourg) National Park, Litchfield National Park, Uluru-Kata Tjuta National Park and Kakadu National Park.

In 2018–19, tourism directly contributed $1.4 billion to the Northern Territory economy. In this period, the sector directly employed nearly 8,500 people but with indirect employment figures this rises to around 15,500 people (Northern Territory Government n.d.).



- Rising temperatures and more extreme heat days can increase heat stress and loss of human life.
- Extreme weather and subsequent flash flooding can increase risks for visitors who are unfamiliar with the local environment and driving conditions.
- Flood and fire can damage infrastructure (including utilities and roads), the environment and ecotourism resources (e.g. wetlands, wildlife habitats and other natural attractions)
- Damage and disruption caused by climate-related events can result in a loss of tourism revenue and jobs.
- Extreme weather and flooding can disrupt transport networks, inhibiting travel within the NT and access to national parks and other popular tourist sites.
- The late retreat of the monsoon in the Top End can shorten the visitor season due to extended seasonal closures. This impacts employment, revenue flows and profitability for the industry. Extended seasonal closures can heavily erode visitor satisfaction with the destination more generally and can negatively affect the intention to travel among potential visitors in the future.
- Key natural systems can be damaged through prolonged or unusual climate events, threatening the viability of marine ecosystems and populations of species such as crocodiles and turtles which are a drawcard for tourism.

Kakadu wetlands

As well as impacts that disrupt access and visitor comfort, climate change could have significant impact on the Territory's natural tourist drawcards. Sea-level rise of 30 cm could cause the loss of 80 per cent of the area of Kakadu's freshwater wetlands (CSIRO 2014), potentially affecting visitation to the area.

4. Responding to change

Territorians need to actively respond to the changing climate in order to maintain sustainable and resilient communities, a healthy environment and a strong economy. Broadly, responding to climate change involves reducing greenhouse gas emissions to limit further change and doing things differently to manage the change that is unavoidable. Individuals, communities, industries and government all have a part to play.

4.1 Mitigation: limiting further change

In order to limit the extent and consequent impacts of climate change, we need to minimise the increases of greenhouse gases in the atmosphere. This can be achieved by reducing emissions and by actively removing gases from the atmosphere by natural or engineered means.

It is important to note that reducing emissions will not immediately halt warming and reduce climate change. Just as a road train suddenly applying the brakes will take some distance to come to a complete stop, global warming resulting from past and current emissions will continue for a long time (decades to centuries).

The Paris Agreement

At the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change in Paris, 195 nations agreed to keep global warming below 2°C above pre-industrial levels, and to actively pursue a target of 1.5°C above pre-industrial levels.

Global warming reached 1°C above pre-industrial levels in 2017, and some regions have already experienced 1.5°C warming (IPCC 2018). Reducing emissions is essential if we are to limit warming to 2°C.

4.2 Adaptation: managing unavoidable change

Maintaining healthy communities, ecosystems and businesses in the face of a changing climate will require changes to how we currently do things. The climate impacts we are already experiencing, and those that are still to come, threaten to cause significant disruption unless we plan ahead and adapt to the changes that we are facing.

Individuals, communities, industries and governments all have a role to play in adapting to climate change. Responses range from practical actions at an individual level (e.g. a primary producer building a shade structure for their livestock) to policy responses at national and global levels.

4.3 What can I do?

Everyone has a part to play in the Territory's response to climate change – individuals, businesses and communities can all take actions to reduce emissions in an effort to limit continuing climate change, and to prepare for the changes that we are already locked into. These actions may include:

- Learning more about what causes climate change and how it will impact you. Reading this report is a great start – so well done!
- Making decisions to reduce your personal environmental footprint, for example by choosing green energy options or recycling and re-using instead of relying on single-use resources. A lot of individual actions by many individuals adds up to a big impact!
- Understanding the climate risks to your community or business and putting plans in place now to either avoid or respond to those risks. Climate change is not something that might or will happen in the future – it's happening now, so the sooner you take action, the better off you'll be!

For more ideas and information visit **https://climatechange.nt.gov.au**

4.4 Find out more

There are many places to find the latest, credible, science-based information about our changing climate. These include:

- National Environmental Science Program Earth Systems and Climate Change Hub – **http://nespclimate.com.au**
- Climate Change in Australia (Australia's national climate change projections) – **https://www.climatechangeinaustralia.gov.au**
- CSIRO – **https://www.csiro.au/en/Research/Climate**
- Bureau of Meteorology – **http://www.bom.gov.au/climate/change/**
- ARC Centre of Excellence for Climate Extremes – **https://climateextremes.org.au**



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APPENDIX:
PROJECTIONS SUMMARY DATA TABLES

Table A1. Change in mean, minimum and maximum temperature (°C) relative to 1995 (1986–2005). Median value is shown with 10th to 90th percentile range.

	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
MONSOONAL NORTH (WEST)									
Annual									
Mean	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (1.0 to 1.8)	1.8 (1.4 to 2.4)	1.0 (0.6 to 1.8)	1.8 (1.3 to 2.8)	3.7 (2.8 to 5.1)
Min	0.7 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.1 (0.7 to 1.4)	0.9 (0.7 to 1.5)	1.3 (1.0 to 1.8)	1.9 (1.4 to 2.4)	1.0 (0.6 to 1.7)	1.9 (1.3 to 2.7)	3.8 (3.1 to 5.2)
Max	0.8 (0.5 to 1.3)	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.1 (0.7 to 1.7)	1.3 (0.9 to 1.9)	1.9 (1.3 to 2.5)	1.0 (0.6 to 2.1)	1.8 (1.3 to 2.9)	3.6 (2.7 to 5.2)
Wet (November–April)									
Mean	0.7 (0.5 to 1.2)	0.8 (0.5 to 1.2)	0.9 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (0.5 to 2.1)	1.8 (1.0 to 2.8)	0.9 (0.5 to 1.8)	1.7 (1.1 to 2.6)	3.3 (2.4 to 5.1)
Min	0.7 (0.5 to 1.1)	0.9 (0.6 to 1.2)	0.9 (0.7 to 1.3)	0.9 (0.7 to 1.5)	1.3 (0.7 to 1.9)	1.9 (1.0 to 2.6)	0.9 (0.6 to 1.6)	1.8 (1.2 to 2.7)	3.6 (2.7 to 5.0)
Max	0.8 (0.5 to 1.4)	0.9 (0.4 to 1.3)	0.9 (0.7 to 1.3)	1.1 (0.6 to 1.8)	1.4 (0.3 to 2.3)	1.8 (0.6 to 3.0)	1.1 (0.5 to 2.1)	1.8 (1.1 to 2.9)	3.4 (2.3 to 5.3)
Dry (May–October)									
Mean	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.4)	0.9 (0.8 to 1.6)	1.5 (0.7 to 2.3)	1.9 (1.1 to 2.7)	1.0 (0.6 to 1.8)	2.0 (1.4 to 2.8)	4.0 (3.2 to 5.2)
Min	0.7 (0.4 to 1.2)	1.0 (0.6 to 1.2)	1.1 (0.8 to 1.5)	0.9 (0.6 to 1.6)	1.4 (0.7 to 2.3)	1.9 (1.2 to 2.8)	1.0 (0.5 to 1.8)	2.0 (1.4 to 2.7)	4.2 (3.5 to 5.4)
Max	0.9 (0.4 to 1.4)	1.0 (0.6 to 1.3)	1.1 (0.7 to 1.4)	1.1 (0.6 to 1.6)	1.4 (0.6 to 2.2)	1.8 (0.9 to 2.9)	1.0 (0.5 to 1.9)	1.9 (1.3 to 2.9)	3.8 (3.0 to 5.1)

	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
RANGELANDS (WEST)									
Annual									
Mean	1.0 (0.6 to 1.4)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.5)	1.2 (0.8 to 1.7)	1.5 (1.0 to 2.1)	2.1 (1.5 to 2.6)	1.1 (0.6 to 1.9)	2.1 (1.5 to 3.1)	4.4 (3.1 to 5.6)
Min	0.8 (0.6 to 1.2)	1.0 (0.6 to 1.4)	1.1 (0.8 to 1.5)	1.0 0.7 to 1.7)	1.4 (1.0 to 2.0)	2.0 (1.6 to 2.6)	1.0 (0.4 to 1.7)	2.0 (1.4 to 2.9)	4.3 (3.3 to 5.6)
Max	1.0 (0.6 to 1.5)	1.1 (0.7 to 1.6)	2.1 (1.6 to 2.8)	1.4 (0.8 to 2.0)	1.6 (1.0 to 2.3)	2.1 (1.6 to 2.8)	1.3 (0.7 to 2.1)	2.3 (1.4 to 3.3)	4.5 (3.1 to 5.8)
Summer									
Mean	0.9 (0.6 to 1.4)	1.0 (0.5 to 1.7)	1.0 (0.7 to 1.6)	1.3 (0.7 to 2.0)	1.5 (0.9 to 2.3)	1.9 (1.2 to 2.8)	1.1 (0.5 to 2.1)	2.2 (1.2 to 3.3)	4.1 (2.6 to 5.9)
Min	0.9 (0.6 to 1.2)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.7)	1.1 (0.7 to 1.8)	1.4 (1.1 to 2.3)	2.0 (1.4 to 2.8)	1.0 (0.6 to 1.8)	2.0 (1.3 to 3.1)	4.1 (2.7 to 5.5)
Max	1.0 (0.6 to 1.6)	1.1 (0.5 to 1.7)	1.1 (0.7 to 1.7)	1.3 (0.8 to 2.1)	1.5 (0.8 to 2.3)	2.1 (1.3 to 2.9)	1.6 (0.5 to 2.6)	2.3 (1.2 to 3.7)	4.1 (2.6 to 6.1)
Autumn									
Mean	1.0 (0.5 to 1.3)	1.1 (0.5 to 1.5)	1.1 (0.6 to 1.6)	1.1 (0.7 to 1.8)	1.4 (0.9 to 2.2)	2.0 (1.3 to 2.7)	1.2 (0.7 to 2.0)	2.1 (1.4 to 3.0)	4.3 (2.5 to 5.8)
Min	0.9 (0.5 to 1.1)	1.0 (0.6 to 1.3)	1.1 (0.7 to 1.6)	1.1 (0.6 to 1.6)	1.5 (0.9 to 2.0)	2.1 (1.5 to 2.7)	1.1 (0.4 to 1.7)	2.1 (1.5 to 2.9)	4.5 (3.0 to 5.8)
Max	1.0 (0.4 to 1.4)	1.1 (0.5 to 1.5)	1.2 (0.5 to 1.7)	1.1 (0.6 to 2.0)	1.5 (0.8 to 2.3)	2.0 (1.2 to 2.9)	1.3 (0.8 to 1.8)	2.2 (1.1 to 3.3)	4.2 (2.8 to 6.0)
Winter									
Mean	0.9 (0.5 to 1.4)	1.0 (0.7 to 1.5)	1.1 (0.8 to 1.6)	1.1 (0.7 to 1.8)	1.5 (0.9 to 2.1)	1.9 (1.5 to 2.5)	1.0 (0.6 to 1.8)	2.1 (1.5 to 2.9)	4.4 (3.3 to 5.4)
Min	0.7 (0.4 to 1.3)	1.0 (0.6 to 1.4)	0.9 (0.3 to 1.2)	1.0 (0.6 to 1.6)	1.3 (0.8 to 2.0)	1.9 (1.5 to 2.5)	0.9 (0.3 to 1.7)	2.0 (1.3 to 2.9)	4.2 (3.3 to 5.3)
Max	1.0 (0.5 to 1.4)	1.1 (0.7 to 1.5)	1.3 (0.8 to 1.7)	1.2 (0.7 to 1.8)	1.7 (1.0 to 2.3)	2.0 (1.6 to 2.6)	1.2 (0.7 to 1.9)	2.2 (1.3 to 3.0)	4.8 (3.3 to 5.6)
Spring									
Mean	0.9 (0.5 to 1.5)	1.1 (0.6 to 1.6)	1.2 (0.7 to 1.6)	1.2 (0.4 to 1.9)	1.6 (1.0 to 2.4)	2.2 (1.5 to 2.9)	1.2 (0.5 to 1.9)	2.2 (1.5 to 3.2)	4.7 (3.3 to 6.2)
Min	0.9 (0.3 to 1.5)	1.1 (0.4 to 1.6)	1.2 (0.6 to 1.7)	1.1 (0.5 to 1.8)	1.5 (0.9 to 2.3)	2.1 (1.5 to 3.0)	1.2 (0.3 to 1.9)	2.2 (1.3 to 3.3)	4.5 (3.4 to 6.0)
Max	1.1 (0.4 to 1.7)	1.1 (0.6 to 1.7)	1.3 (0.7 to 1.8)	1.4 (0.3 to 2.1)	1.7 (0.9 to 2.6)	2.2 (1.6 to 2.9)	1.3 (0.5 to 2.1)	2.4 (1.3 to 3.4)	4.7 (3.3 to 6.2)

Table A2. Annual number of days over 35°C and 40°C. Towns shaded green are in the Monsoonal North cluster and towns shaded orange are in the Rangelands cluster. Value is average of eight models and range is lowest and highest model value. (Source: www.climatechangeinaustralia.gov.au)

Threshold	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
MILIKAPITI							
35°C or above	6	23 (13 to 39)	28 (14 to 50)	41 (24 to 67)	65 (34 to 102)	70 (42 to 102)	205 (155 to 250)
40°C or above	0	0	0	0	0	0	0
DARWIN							
35°C or above	47	107 (80 to 133)	118 (82 to 156)	139 (108 to 172)	176 (136 to 209)	184 (152 to 214)	288 (256 to 317)
40°C or above	0	0	0	0	0	0	5 (1 to 11)
JABIRU							
35°C or above	135	191 (169 to 214)	198 (172 to 224)	212 (187 to 233)	238 (203 to 267)	243 (219 to 266)	310 (284 to 332)
40°C or above	2	7 (3 to 11)	8 (3 to 13)	12 (5 to 21)	21 (8 to 31)	19 (9 to 28)	70 (29 to 111)
NHULUNBUY							
35°C or above	7	17 (12 to 22)	19 (14 to 27)	26 (18 to 35)	38 (23 to 53)	38 (26 to 51)	121 (80 to 173)
40°C or above	0	0	0	0	0	0	0
BATCHELOR							
35°C or above	86	142 (119 to 160)	153 (124 to 180)	168 (144 to 193)	199 (168 to 226)	205 (177 to 229)	291 (261 to 318)
40°C or above	0	1 (1 to 2)	2 (1 to 3)	2 (1 to 4)	5 (2 to 8)	5 (2 to 7)	32 (10 to 53)
PINE CREEK							
35°C or above	110	159 (137 to 176)	169 (146 to 188)	179 (160 to 197)	208 (181 to 231)	211 (187 to 230)	282 (253 to 309)
40°C or above	1	4 (1 to 6)	4 (2 to 9)	7 (3 to 12)	14 (5 to 22)	12 (5 to 20)	57 (17 to 90)
KATHERINE							
35°C or above	157	200 (178 to 214)	208 (189 to 220)	216 (198 to 231)	240 (218 to 255)	242 (225 to 255)	298 (274 to 320)
40°C or above	7	19 (11 to 27)	22 (14 to 35)	28 (18 to 39)	43 (24 to 57)	38 (21 to 51)	101 (54 to 138)
BORROLOOLA							
35°C or above	125	154 (134 to 167)	164 (144 to 179)	171 (149 to 189)	194 (170 to 213)	196 (178 to 213)	255 (221 to 286)
40°C or above	5	11 (7 to 14)	12 (8 to 18)	15 (9 to 23)	24 (13 to 37)	21 (12 to 35)	69 (29 to 98)
ELLIOTT							
35°C or above	182	211 (198 to 224)	216 (198 to 226)	222 (203 to 237)	239 (222 to 253)	241 (226 to 250)	280 (248 to 300)
40°C or above	46	67 (54 to 78)	73 (55 to 91)	80 (66 to 96)	101 (76 to 125)	96 (78 to 114)	153 (99 to 185)
TENNANT CREEK							
35°C or above	136	160 (147 to 175)	166 (149 to 180)	169 (150 to 188)	188 (168 to 205)	187 (167 to 205)	228 (178 to 252)
40°C or above	22	40 (27 to 57)	45 (26 to 69)	50 (35 to 75)	68 (43 to 99)	61 (39 to 89)	115 (60 to 150)
ALICE SPRINGS							
35°C or above	90	110 (100 to 124)	113 (100 to 130)	118 (103 to 144)	135 (112 to 160)	132 (113 to 158)	172 (121 to 205)
40°C or above	14	27 (17 to 44)	29 (18 to 50)	35 (21 to 61)	48 (30 to 76)	43 (28 to 69)	86 (40 to 128)
YULARA							
35°C or above	104	122 (111 to 133)	124.68 (116 to 140)	130 (117 to 151)	145 (127 to 169)	143 (126 to 161)	178 (134 to 207)
40°C or above	26	42 (32 to 61)	44 (34 to 63)	50 (39 to 74)	63 (46 to 93)	59 (46 to 80)	99 (57 to 140)

Table A3. Change in average rainfall (%) relative to 1995 (1986–2005). Note that changes in the dry season can appear large because they are changes on a small amount.

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-2 (-10 to +5)	0 (-11 to +6)	0 (-6 to +6)	-3 (-10 to +5)	0 (-10 to +7)	-1 (-14 to +9)	-5 (-11 to +4)	-1 (-13 to +8)	+4 (-24 to +19)
Wet	0 (-8 to +6)	0 (-8 to +6)	-1 (-5 to +7)	-3 (-10 to +6)	+1 (-7 to +7)	0 (-7 to +8)	-3 (-11 to +5)	0 (-11 to +8)	+4 (-23 to +19)
Dry	-7 (-32 to +17)	-5 (-35 to +19)	-5 (-22 to +29)	-11 (-27 to +12)	-11 (-35 to 5)	-6 (-40 to +26)	-7 (-29 to +7)	-6 (-30 to +22)	-4 (-45 to +44)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-2 (-12 to +7)	-2 (-11 to +7)	-1 (-11 to +8)	-4 (-18 to +4)	-1 (-12 to +8)	-2 (-17 to +9)	-7 (-19 to +3)	-5 (-16 to +9)	-4 (-31 to +19)
Summer	-4 (-13 to +8)	0 (-12 to +8)	0 (-11 to +17)	-5 (-17 to +7)	+1 (-12 to +13)	-1 (-16 to +13)	-7 (-22 to +8)	-3 (-17 to +10)	+4 (-21 to +26)
Autumn	-2 (-18 to +25)	-1 (-24 to +22)	0 (-24 to +20)	-1 (-26 to +21)	-1 (-17 to +21)	+1 (-20 to +22)	-7 (-24 to +20)	-2 (-22 to +33)	6 (-40 to +39)
Winter	-3 (-22 to +11)	-7 (-27 to +19)	-10 (-31 to +18)	-8 (-37 to +13)	-9 (-30 to +9)	-10 (-32 to +23)	-6 (-35 to +15)	-11 (-32 to +7)	-22 (-58 to 35)
Spring	-3 (-22 to +21)	-1 (-25 to +22)	-3 (-20 to +13)	-6 (-39 to +14)	-4 (-29 to +12)	-4 (-39 to +18)	-5 (-31 to +17)	-9 (-32 to +12)	-14 (-53 to +26)

Table A4. Change in relative humidity (%) relative to 1995 (1986–2005).

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-0.5 (-2.2 to 0.5)	0.1 (-1.6 to 0.7)	-0.3 (-1.3 to 0.4)	-0.9 (-2.2 to 0.9)	-0.4 (-2.2 to 0.8)	-0.5 (-2.3 to 0.9)	-1.0 (-3.1 to 0.4)	-0.7 (-3.5 to 0.6)	-0.9 (-6.3 to 1.4)
Wet	-1.0 (-2.7 to 1.1)	-0.5 (-2.3 to 1.5)	-0.9 (-2.8 to 0.8)	-1.0 (-4.8 to 0.5)	-0.8 (-4.6 to 3.4)	-0.9 (-5.6 to 3.2)	-2.1 (-4.7 to 0.1)	-1.3 (-5.0 to 1.0)	-1.7 (-7.2 to 3.0)
Dry	-0.9 (-3.3 to 0.8)	-0.5 (-3.4 to 1.8)	-0.7 (-2.7 to 1.3)	-1.7 (-3.6 to 1.8)	-1.0 (-6.7 to 3.7)	-1.3 (-6.1 to 3.5)	-1.0 (-5.2 to 0.6)	-1.0 (-6.6 to 1.3)	-2.0 (-12.5 to 3.2)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-0.6 (-3.1 to 0.7)	-0.3 (-2.1 to 0.8)	-0.7 (-1.9 to 0.9)	-0.6 (-2.9 to 0.3)	-0.5 (-4.0 to 1.1)	-1.0 (-3.3 to 0.9)	-1.5 (-3.5 to 0.1)	-1.1 (-4.8 to 0.1)	-1.9 (-7.3 to 1.1)
Summer	-1.2 (-3.6 to 1.3)	-0.4 (-2.7 to 1.6)	-0.4 (-2.4 to 1.4)	-1.0 (-3.4 to 0.4)	-0.3 (-3.2 to 1.8)	-0.9 (-4.7 to 1.3)	-2.8 (-4.6 to 1.0)	-0.6 (-5.2 to 1.1)	-1.2 (-6.3 to 2.4)
Autumn	-0.7 (-5.6 to 3.2)	-0.3 (-4.2 to 2.4)	-0.5 (-2.9 to 2.0)	-0.1 (-6.3 to 2.5)	-0.7 (-4.5 to 2.6)	-1.0 (-5.8 to 3.2)	-2.0 (-4.7 to 1.2)	-0.9 (-7.7 to 3.0)	-1.4 (-10.6 to 4.3)
Winter	-0.7 (-3.3 to 1.0)	-0.7 (-3.1 to 0.9)	-1.1 (-3.3 to 0.5)	-1.3 -3.9 to 0.3)	-1.4 (-4.5 to 0.4)	-1.2 (-5.2 to 2.1)	-1.1 (-4.3 to 1.0)	-1.8 (-5.1 to -0.1)	-3.7 (-10.9 to 0.3)
Spring	-0.6 (-4.5 to 1.4)	-0.5 (-3.4 to 1.3)	-0.5 (-3.0 to 1.1)	-0.9 (-3.5 to 1.8)	-0.8 (-2.9 to 1.5)	-0.6 (-3.8 to 1.5)	-0.8 (-4.0 to 0.9)	-1.5 (-4.1 to 1.1)	-2.7 (-7.3 to 1.5)

Table A5. Change in potential evapotranspiration (%) relative to 1995 (1986–2005).

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	2.8 (1.4 to 3.6)	3.2 (1.4 to 4.0)	3.2 (2.1 to 4.8)	3.4 (1.5 to 5.1)	4.3 (1.9 to 6.8)	6.2 (4.1 to 8.3)	3.6 (2.2 to 5.8)	6.8 (4.0 to 8.5)	12.2 (7.8 to 16.7)
Wet	Not available	2.8 (1.0 to 4.1)	3.1 (1.5 to 4.2)	Not available	3.8 (0.4 to 7.6)	5.1 (1.5 to 9.5)	Not available	5.9 (2.9 to 8.2)	9.9 (4.9 to 14.9)
Dry	Not available	3.4 (1.4 to 5.3)	3.8 (2.5 to 5.0)	Not available	4.8 (1.8 to 7.8)	7.2 (3.2 to 10.4)	Not available	6.7 (4.8 to 8.9)	14.4 (10.6 to 18.2)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	2.8 (1.0 to 4.5)	2.4 (1.1 to 4.5)	3.1 (1.4 to 4.2)	3.4 (-0.6 to 5.2)	4.5 (1.6 to 6.6)	5.5 (3.1 to 7.9)	2.5 (-0.4 to 4.5)	5.1 (3.3 to 8.4)	11.7 (6.7 to 17.7)
Summer	2.6 (1.5 to 4.0)	2.6 (0.8 to 4.5)	2.8 (1.2 to 5.1)	3.3 (0.7 to 4.7)	4.8 (1.0 to 7.7)	5.3 (3.1 to 7.9)	2.3 (0.1 to 6.4)	5.2 (3.0 to 9.5)	12.2 (7.8 to 17.3)
Autumn	2.4 (0.4 to 6.1)	3.1 (-0.9 to 4.9)	2.6 (0.1 to 6.0)	3.2 (-0.7 to 8.6)	4.4 (0.6 to 8.3)	6.0 (3.9 to 12.2)	2.0 (-1.1 to 6.1)	5.7 (2.3 to 10.2)	13.8 (6.1 to 20.4)
Winter	2.4 (-0.2 to 4.4)	2.4 (-0.2 to 5.5)	2.3 (-0.5 to 5.3)	2.8 (0.2 to 6.7)	3.6 (0.4 to 6.6)	4.5 (0.8 to 10.0)	2.3 (-1.8 to 6.7)	5.1 (1.7 to 8.8)	11.8 (3.8 to 18.2)
Spring	2.6 (-0.7 to 6.6)	2.8 (-0.1 to 5.4)	2.7 (0.7 to 5.7)	2.9 (-1.3 to 5.5)	3.6 (1.0 to 6.8)	5.1 (1.1 to 8.7)	1.8 (-0.9 to 4.8)	5.0 (1.6 to 7.8)	10.7 (4.2 to 16.1)

Table A6. Projected sea-level rise and allowances (m) relative to 1986–2005 for coastal local government areas in the Northern Territory. (Source: CoastAdapt at www.coastadapt.com.au)

LGA	2030 (2020–2040)			2050 (2040–2050)			2090 (2080–2100)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Belyuen									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
Darwin									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
East Arnhem									
SLR	0.11 (0.07 to 0.16)	0.11 (0.07 to 0.16)	0.12 (0.07 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.54)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.11	0.12	0.12	0.21	0.22	0.25	0.43	0.51	0.70
Litchfield									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.53	0.73
Roper Gulf									
SLR	0.11 (0.06 to 0.15)	0.11 (0.07 to 0.15)	0.11 (0.07 to 0.16)	0.19 (0.11 to 0.27)	0.20 (0.13 to 0.28)	0.23 (0.15 to 0.31)	0.35 (0.19 to 0.51)	0.43 (0.26 to 0.61)	0.59 (0.38 to 0.81)
Allowance	0.11	0.11	0.11	0.20	0.21	0.24	0.39	0.47	0.65
Tiwi Islands									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.45	0.53	0.73
Victoria Daly									
SLR	0.11 (0.07 to 0.15)	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.53)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.12	0.12	0.12	0.21	0.23	0.26	0.43	0.51	0.71
Wagait									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
West Arnhem									
SLR	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.21 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.39 (0.22 to 0.56)	0.46 (0.29 to 0.65)	0.62 (0.41 to 0.85)
Allowance	0.12	0.13	0.13	0.23	0.25	0.28	0.52	0.61	0.85
West Daly									
SLR	0.11 (0.07 to 0.15)	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.53)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.12	0.12	0.12	0.21	0.23	0.26	0.43	0.51	0.71







Earth Systems and Climate Change Hub

National Environmental Science Programme

NORTHERN TERRITORY GOVERNMENT

[redacted]

From: Protect Big Rivers <protectbigrivers@gmail.com>
Sent: Tuesday, 9 January 2024 11:04 PM
To: tamboran DEPWS; Onshoregas DEPWS
Subject: EMP 98&117 Submission
Attachments: EMP Tamboran 912023 .pdf; Haswell Report .pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please find Protect Big Rivers submission and Attachment 1 'The Haswell Report', attached.
Kind regards,
Dr Samantha Phelan
Secretary
Protect Big Rivers.

[redacted]

From: Protect Big Rivers <protectbigrivers@gmail.com>
Sent: Wednesday, 10 January 2024 12:00 AM
To: tamboran DEPWS; Onshoregas DEPWS
Subject: Re: EMP 98&117 Submission
Attachments: EMP Tamboran 912023 FINAL .pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Apologies the incorrect submission was attached.
Please replace submission with this version. The Haswell Report remains as Attachment 1.
Regards,
Sam Phelan
PBR.

On Tue, Jan 9, 2024 at 11:03 PM Protect Big Rivers <protectbigrivers@gmail.com> wrote:

> Please find Protect Big Rivers submission and Attachment 1 'The Haswell Report', attached.
> Kind regards,
> Dr Samantha Phelan
> Secretary
> Protect Big Rivers.

SUBMISSION, BEETALOO BASIN
EP 98, EP 117

INTRODUCTION

Protect Big Rivers (PBR) is a community-based incorporation based in the Big Rivers Region of the Northern Territory (NT). Our members are Territorians concerned about water and climate security in our region.

Members of the Big Rivers region are familiar with contaminated drinking water, unrelated to hydraulic fracturing. We live with ongoing PFAS contamination of our children, our aquifer, our swimming holes, our rivers and our wild caught food supplies. We have some of the highest PFAS levels in Australia in our bloodstreams.

We know it is unlikely we will be able to ever prove that our autoimmune diseases, diabetes, high cholesterol, renal cancers, testicular cancers, low birth weight babies, or thyroid problems are directly attributable to our PFAS ingestion, despite medical data now attributing all of these diseases to PFAS.[1] The small, mobile population of the Katherine Region is unlikely to be 'statistically significant' as diseases progress. To the unwell individuals however, each illness is heartbreakingly significant.

A critical function of Government is to prevent such disasters recurring. This EMP contains significant information, and omissions, that should flag to Government that unconventional gas expansion in the Beetaloo Basin may unintentionally result in a repeat of the PFAS style contamination event.

The Government has a responsibility to keep water safe. In the Big Rivers Region, this includes the responsibility of protecting the unique cultural value of water for Aboriginal people. Whilst much of this cultural knowledge is protected, it is critical that Government and fracking companies recognise that threatening water, threatens Aboriginal culture in the Territory to its core. It is 'ground zero'.

This submission will focus on

1. Free prior and informed consent of people living in the regions most affected by fracking.
2. Emerging data related to the adverse health consequences of unconventional gas development.
3. The chemical risk assessments contained in the EMP.
4. The risk to both surface and subsurface water supply contained in the EMP.
5. The risk to fauna in the region.

[1] https://setac.onlinelibrary.wiley.com/doi/epdf/10.1002/etc.4890

FREE PRIOR AND INFORMED CONSENT

We must emphasise that timeframes of this consultation period are extremely disappointing. If the government is seeking true informed consent, local decision making, and community feedback, then releasing over 3600 pages of highly technical information to the public over the Christmas school holidays is a poor way to go about it. Sadly, now par for the course, it is inconsistent with good policy and good process, and speaks, with the exception of the Pepper Inquiry, to the lack of meaningful consultation that has plagued the onshore unconventional gas industry in the Territory.

In addition to school holidays, Christmas, and New Year falling within the exhibition period, some of the most directly affected people - traditional owners, native title holders and residents of Elliott, conduct ceremony in the first weeks of January. Many people indicated, that whilst wanting to comment on this plan, they either did not know about it in time, could not access the document due to having no access to appropriate technology, and had to prioritise ceremony. Many residents, reliant on the surface and groundwater from these proposed fracking sites, still have no knowledge of this EMP.

Tamboran states consultation with affected traditional owners has taken place in the form of private consultation with native title holders and larger community meetings. Protect Big Rivers has been contacted by numerous affected families from the Elliot and Barkly who are concerned that they have not been notified of these meetings.

As we create this submission 11 am, on 9/1/2024, the portal for making submissions has been prematurely removed from the 'Have Your Say' website prior to the close date and time. All office staff are on holidays and the portal cannot be reopened. This is unlawful – section 28(1A) of the *Interpretation Act NT* (1978) states "if an Act provides that a period of time ends at, with or on a given day, act or event, the time is reckoned to include that day or the day of that act or event". It is unclear how many people have not been able to provide their comments within the statutory time period. This is the system of governance we a required to believe can regulate massive unconventional gas expansion in the NT.

We also note in relation to consultation:

Pepper Recommendation 11.5

That interpreters be used at all consultations with Aboriginal people for whom English is a second language. Interpreters must be appropriately supported to ensure that they understand the subject matter of the consultation. Many residents of Elliot testify to the fact that no translators have been present at meetings, and that senior people in their community, with ultimate decision-making authority, continue to have little understanding of the nature of this industry.

Pepper Recommendation 11.6

That in collaboration with the Government, Land Councils and AAPA, an independent, third-party designs and implements an information program to ensure that reliable,

accessible, trusted and accurate information about any onshore shale gas industry is effectively communicated to all Aboriginal people who will be affected by any onshore shale gas industry. That the program be funded by the gas industry. Again, many members of Protect Big Rivers, including Elliot residents, highlight this as an ongoing problem. This work has not been conducted adequately and people across the board feel they are ill-equipped to make decisions about their country in relation to this industry. This problem was noted to be unresolved during the SREBA social and cultural study where the author states quite clearly.

- *'Many people did not feel they have been consulted adequately. There is not widespread understanding of what onshore gas development will look like, or what impacts it may have for the region. It is felt that only those directly impacted have had the industry explained to them. There is a desire for more "neutral", "factual" information.'*

- *'Even some of the people who have been highly engaged feel conflicted or confused because they are hearing "two very different sides to the story". It was explained how information is needed that can empower local people to raise their concerns about (onshore gas and any other) proposed development or to make suggestions for how to improve practices.'* [2]

The work required to assist the most affected communities to understand the inherent risks of this industry, and to protect country, culture, water, and climate for future generations, remains incomplete. People request that unbiased information is presented in person, in open community meetings, with adequate notice to invite family members and other interested parties who may be working away. It is imperative that this occurs before a project of the scale proposed in this EMP is approved.

POTENTIAL HEALTH RISKS OF SHALE FRACKING

The cumulative negative impacts of exploration creep were highlighted in the Pepper Inquiry. This 19 well EMP reflects exploration creep. It requires robust consideration at a population and environmental health level.

In 2023 a medical publication synthesised the emerging peer reviewed medical literature on the human health implications of the oil and gas industry, known as 'The Haswell Report'. [3] It is now well documented that people exposed to oil and gas operations experience 'significant harm'. Much of this information was unavailable at the time of the Pepper Inquiry. The report is attached to this submission as Attachment 1.

[2] https://territorystories.nt.gov.au/10070/903893

[3] https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/6034629d171899f2c6ce54ac91c4d0a9a3fbee4a/original/1702361376/1331dbeadf17ed32a597b21dd9c2adb1_risks_of_og_development_%282%29.pdf?1702361376&utm_campaign=website&utm_medium=email&utm_source=ehq

It is critical that this medical literature is considered more robustly prior to approving this EMP.

The literature proves exposure to shale fracking can cause

- reproductive harms and interference with development of unborn babies, including higher risks of low birth weight, pre-term delivery and spontaneous abortion.
- higher risk of acute lymphoblastic leukemia.
- higher risk of severe birth defects
- higher hospitalisation and death rates due to heart attacks, heart failure, respiratory diseases and some cancers
- increases in depression, anxiety and social withdrawal, especially among young and pregnant women
- higher injury and fatality rates due to increased heavy vehicle traffic
- increases in sexually transmitted infections associated with the industry's mobile workforces
- more severe asthma in children requiring more medical treatment, emergency department visits and hospitalisations.

To even begin to assess the population health impacts of this industry it is critical to have a robust health baseline. ***The SREBA health studies form an inadequate baseline by their authors own admission***, failing as:

- Data from Sunrise Health (Jilkminggan, Mataranka, Minyerri clinics) could not be accessed in time for study completion so was not included in the data.
- The data from Elliott was not robust, with 40% of primary presenting complaints not being recorded on medical files.
- Symptoms commonly associated with gas fields – sore eyes, nosebleeds, skin rashes and headache are transitory and self-managed illnesses so will be underrepresented in health clinic presentations.
- Low population numbers making the population health data not statistically significant.
- No health monitoring or survey plans have been developed.
- It was 'very much a first step and requires engagement into an implementable plan'.[4]

Much has been said by the Northern Territory Government of the Haswell Report data coming from poorly regulated gas fields in the USA, which will not compare to the NT's 'world class regulatory regime' and remote context. However, a systematic analysis of the

[4] https://www.youtube.com/watch?v=nLrzdiHO8Ho&list=PLP09nyCPXGKxe4sZzzF9Pdb7rc1F_yJpP&index=8

adverse health findings contained within the Haswell Report show they are consistent across diversities of landscape, geography and location of gas plays, the quality of the regulatory regime overseeing them, the people and population density.

With the incomplete implementation of the Pepper Inquiry recommendations,[5] and PBRs experience of the regulatory follow up of the Tamboran wastewater contamination event, the robust nature and capacity of the regulatory regime is questioned.

Many of the pathways of exposure to industry toxins remain poorly understood and incomplete. When health problems are identified and investigated, more contamination pathways are found. It is therefore ***critical that exposure pathways are rigorously considered and contextualised to the people, culture, and practices of the country they are taking place on, prior to the adverse cumulative health impacts of the industry being experienced.*** This has not occurred in this EMP, and results in incomplete risk pathways in regard to potential human contamination.

Prior to any further exploration taking place in the Beetaloo it is critical that adequate baseline health data is compiled. The SREBA Health Studies must be repeated, in a more comprehensive way, and be fit for purpose, prior to any further exploration creep.

CHEMICAL RISK ASSESSMENTS – GENERAL

Half of the 3645 pages of this EMP are dedicated to chemical risk assessments. The chemical safety data sheets speak to surfactants, acids, bactericides, glycols and other chemicals that are 'commercial in confidence'.

The EMP states that nearly 1.5 million litres of various chemicals used for well 'stimulation' will be stored on each lease pad, assuming 3 wells per pad. That alone is a significant risk given there is the assumption of chemical storage over wet seasons.

The chemical risk assessments have been outsourced to 2 separate companies, being AECOM and Condor.

Tier 1 chemicals are characterised as chemicals of low human health and ecological concern. Tier 2 chemicals require an additional risk assessment to characterise potential risks.

The EMP states '*chemical risk assessments have been completed for all chemicals to be used in drilling and HFS. All chemicals were considered low concern when standard chemical handling, storage and disposal practices were applied (Appendix E and Appendix E.1)*.' PBR do not accept this statement as factual. AECOM's conclusions need to be put to a more robust process of peer review prior to being accepted.

The chemical risk assessment process is not robust nor protective:

[5] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj-mcilm8-DAxVqSGwGHTnVAZgQFnoECA4QAQ&url=https%3A%2F%2Fwww.aph.gov.au%2FDocumentStore.ashx%3Fid%3D25b0f75c-47f9-4564-8928-09f0f07f653d&usg=AOvVaw1xy-i4SGkKV5OWqYhxMA_V&opi=89978449

- Historical failure of chemical risk assessments has, in part, resulted in the adverse health outcomes related to chemical contamination by the industry highlighted in the Haswell Report.

- The use of private consultancy firms for chemical risk assessment creates inherent bias. No toxicological peer review was possible within the given timeframe**.** However, AECOM was subjected to independent examination during the Pepper Inquiry where the report concluded in relation to AECOM assessment of potential groundwater contamination:

  'The panel is critical of this risk assessment insofar as possible exposure pathways were excluded as not being complete (that is, one or more steps in the exposure pathway were assessed to be missing). But, surprisingly, based on the assumed success of the risk mitigation measures that Origin proposed, AECOM assessed that there were no pathways by which hydraulic fracturing chemicals could have an impact on beneficial groundwater in the project area.' [6]

- The chemical risk assessments largely relate to worker exposure, rather than chronic exposure pathways of soil, air, water and wildlife and food chains, and are therefore incomplete.
- Risk assessments assume that accidents will be minimal and that potential for contamination of the environment is therefore small. Accumulated incidences from early exploration activities, particularly in relation to Tamboran, have already demonstrated this is not the case.
- Remoteness and extreme weather conditions increase the risk attached to the process considerably yet is poorly considered in the EMP.
- Many chemical toxicities are classified on the basis of acute OR chronic grounds, rather than both. Consistent reasoning behind this method of assessments seems unclear.
- There is a consistent theme of chemical disclosures being incomplete, not disclosed at all or redacted. Chemical disclosures are incomplete despite Pepper inquiry recommendation 7.10:

  That prior to the grant of any further exploration approvals, the following information about hydraulic fracturing fluids must, as a matter of law, be reported and publicly disclosed before any exploration activities and production activities are carried out:

  - *the identities, volumes and concentrations of chemicals (including environmentally relevant chemical species present as contaminants in the bulk chemicals) to be used*

6

A. Chemical tracers

The chemical tracer risk assessment is probably the clearest example of non-transparent chemical disclosure. All of the 4 chemicals are listed as proprietary. All warrant a Tier 2 screen. No chemical name or formulation is available for public scrutiny. The toxicity summaries in Appendix E have all references redacted.

In addition:

- The 4 undisclosed chemicals are listed in the Human Health Assessment for the chemical tracers. However, the description of 'one chemical selected to represent a group of (15 or) 20 similar chemicals' in the table seems to imply the proponent will use 37 chemicals, only 4 of which have been health screened by AECOM for the purposes of this EMP.
- 16 of these chemical tracers are not readily biodegradable, yet the toxicity screen relates only to 2 chemicals, both for acute exposure, rather than chronic exposure.
- 2 of the chemicals are highly ecotoxic to aquatic species at concentrations used.

The disclosure and risk assessment of these chemicals is plainly inadequate and not in line with Pepper recommendation 7.10.

B. Drilling fluids

The AECOM Appendix E chemical risk assessment states none of the chemicals proposed for use in this EMP's drilling fluids are identified as being toxic AND persistent AND bio accumulative. This however means some chemicals used in the drilling fluids may be toxic and persistent, or toxic and bio accumulative. The failure to adequately categorise these chemicals is a notable omission.

In a dangerous omission from the code, there is no requirement for companies to test drill waste prior to removing from the sump. There is no requirement to test for heavy metals, radiation (NORMS) and chemical content prior to disposal, which may take years. As this pathway for potential contamination has already been proved in the Maverick 1 incident the code requires immediate revision**.**

Section 3.1.12 Table 11 and 12 contain a total of 46 individual drilling fluid chemicals assessed as Tier 2 chemicals, i.e.: requiring an additional risk assessment to characterise potential risks. Three of these drilling chemicals are 'proprietary' with CAS numbers withheld.

These chemicals appear to be documented as they are part of commercially available drilling fluid mixtures. The Safety Data Sheets (SDS) for the commercial drilling fluid mixtures are contained in Appendix J, however their CAS numbers are again redacted so what chemical is in what fluid is masked.

The SDS summary below speaks to the fact that there is frequently little data available related to the long-term health impacts of these chemical mixtures in the environment, regardless of their individual chemical components. Examples are:

NewPerm NF, CAS number withheld – Hexanedinitrile, hydrogenated

- Basic human health acute toxicity specific test data for the substance is not available
- No data for bio accumulative potential
- Considered biodegradable but after 28 days in sea water only 62% of the chemical had biodegraded
- No information available on carcinogenicity, reproductive toxicity, germ cell mutagenicity.

AVAGLYCO LC, no CAS number provided, no chemical name provided

- Information provided in SDS Appendix J
- 'The environmental impact of this product has not been fully investigated'
- Contains 100% of components with unknown hazards to aquatic environments
- No information available on persistence, degradability or bioaccumulation
- No information available on endocrine disrupting properties.

Triethanolamine, no CAS number provided, product also contains diethanolamine

- No ecological toxicity, persistence, biodegradability, bio accumulative potential or soil mobility data provided.

The SDS provided in the EMP states there is insufficient data to classify the product as carcinogenic, or a mutagen or reproductive toxin. However, another SDS found researched by PBR , containing diethanolamine and triethylamine states 'Suspected of damaging fertility. Contains Diethanolamine, toxicity to male reproduction may occur. Testicular effects have been found after repeated exposures."[7] This would imply the product may be an endocrine disrupter although this conclusion is not drawn by AECOM.

Top Spot – no CAS number provided, surfactant

No information about this chemical is provided in the SDS at all. The chemical composition is unknown, there is no CAS provided, and the chemical has no information related to ecological toxicity, bio accumulative potential, persistence and degradability and mobility in soil.

Tru Scav HD, no CAS provided, oxygen scavenger, strong oxidising agent

[7] https://chemistryconnection.com/sds/data/pdf/TEA99_SDS.pdf

From SDS provided - The environmental impact of this product has not been fully investigated. No information is available as to persistence, degradability, bio accumulative potential, soil mobility.

Avadefoam NS, no CAS provided, proprietary, defoamer

From SDS provided – the environmental impact of this product has not been fully investigated. No information is available as to carcinogenicity, reproductive toxicity, germ cell mutagenicity, persistence and degradability, bio accumulative potential.

Barite Powder, no CAS provided

Barium sulfate is one of the main ingredients. It is classified in the SDS as non-biodegradable and 'not expected to cause adverse effects to animal or plant life if released into the environment in small quantities.' What a 'small quantity' is not defined in the risk assessment.

Again, to bring local context to this, Barium was one of the ingredients found in the water being illegally spread onto the breeder paddock on Tanumbirini Station following the Tamboran dust suppression incident.

Although barite (component of fluids used in drilling of the oil and gas) has low solubility, it can still release amounts of Ba2+ in negatively charged soil colloids, posing a potential toxicity risk to plants and invertebrates.[8]

EvoConE, no CAS provided, Poly (oxy-1,2-ethanediyl), alpha-octyl-omega-hydrox-

From SDS provided, there is 'no information available' in relation to carcinogenicity, reproductive toxicity, toxicity, persistence and degradability, bio accumulative potential, soil mobility. It appears the chemical name may be incomplete.

EvoLube G, no CAS provided, petroleum distillate, hydrotreated light

From SDS provided no information available on soil mobility, persistence, biodegradability. The bio accumulative potential is incomplete on document.

Idicide G50, no CAS provided, glutaraldehyde and methyl alcohol

From SDS provided there is no information available as to carcinogenicity, reproductive toxicity, persistence and biodegradability, bioaccumulation.

Glutaraldehyde is known to be very toxic to aquatic species.

NDFT 325, no CAS provided, 2 components listed as trade secrets, contains Amine 2, ethylamine, N-ethyl-N-hydroxy-, Amine 1 and ethanolamine

[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8020924/#fsn32177-bib-0020

From SDS provided there is no information available as to carcinogenicity and reproductive toxicity. The environmental impact of this product has not been fully investigated.

With so little data available in relation to these drilling fluid mixtures, and in light of previous contamination incidents, significantly more consideration needs to be given to reducing the risk of contamination of water ways by drilling waste than is required either by the code or considered by Tamboran in this EMP.

C. Hydraulic stimulation fluids

Given the large volumes of these chemicals being trucked and stored, and that many risk pathways remain incomplete, as per Table 18, independent examination of the toxicology contained in the chemical health risk profiles is required.

There are many phrases throughout the chemical risk assessments such a 'not expected to be' carcinogenic for example, or 'not likely to have' a toxic effect. This implies there is a complete or partial absence of safety data, yet chemicals have been classified as Tier 1 chemicals on the basis of these assumptions.

Each SDS has the disclaimer 'The information contained herein may not be valid when this product/material is used in combination with any other product/material or process.' Given all chemicals are mixed with other products, and all are exposed to the processes of heat and pressure, each SDS may not be valid when these fluids are then stored in flowback water.

A sample list of chemicals of concern in the fracking stimulation fluids are listed below. It is worth noting that "Table 6 – The chemical risk assessment of stimulating fluids" is incomplete. Some of the particularly toxic chemicals used in fracking fluids are omitted from the initial chemical list in and can only be found buried in the depths of the 1800 pages in Appendix E.

Acrylonitrile CAS 107-13-1. Omitted from Table 6, only found in appendix E
This product 'may cause cancer' and 'is toxic to aquatic life with long lasting effects'.

Poly tetrafluoroethylene CAS 9002-84-0. Omitted from Table 6
This is a PFAS chemical otherwise known as Teflon. AECOM has classified as a Tier 1 chemical requiring no further assessment. This is despite documentation provided stating:

- It is not biodegradable
- There is no data available on its carcinogenicity or chronic toxicity, or genotoxicity, or reproductive toxicity, or developmental toxicity
- There is limited information available for aquatic toxicity
- It is 'not expected' to be bioavailable due to its high molecular weight.

Whilst PBR recognises PTFE is a longer chain PFAS chemical, the risk of the polymer chain collapsing into the short chain PFA chemicals, in the high heat and pressure environment of

a fracking hole, is not considered in this EMP. Regardless, this chemical is still a 'forever' PFAS chemical.

Tributyl tetradecyl phosphonium chloride. Omitted from Table 6. Found in appendix E
No SDS provided. Tier 2 classification. 2370 litres stored on well pad.
Very high acute toxicity.
From online SDS: toxic to aquatic systems with long lasting effects, no information available on bioaccumulation.

DCA-17001
3000L stored on each well pad. Prolonged or repeated exposure may cause eye, blood, lung, liver, kidney, heart, central nervous system and spleen damage.
May cause harm to unborn child.
Very ecotoxic in the aquatic environment. Very ecotoxic in the soil environment.

DCA 19001
Disodium octaborate tetrahydrate, 1800kg stored per well pad. Suspected of damaging fertility or the unborn child. Toxic to algae fish and invertebrates.

DCA 19002
Mixture of Ulexite, Ethylene Glycol and Silica. 30,000L stored per well pad.
Prolonged or repeated exposure may cause embryo and foetus toxicity. Prolonged or repeated exposure may cause reproductive system damage. Repeated overexposure may cause liver and kidney effects.

DCA 32002
Surfactant 45,000L stored per well pad. Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

DCA 32014
Surfactant 600L per well pad. Prolonged or repeated exposure may cause reproductive system damage. May cause birth defects.

Alcohols, C11-14-iso-, C13-rich, ethoxylated- surfactant
15,000L stored per well pad. Acute hazard in aquatic environment, harmful to aquatic life with long lasting effects.

Assumptions made within the consultants Tier 2 classifications in this EMP also require further scrutiny than time available permits. Tier 2 chemicals are inherently more dangerous than Tier 1 chemicals. Toxicity summaries considered by the consultants are then created to further assess chemical risk. However, the conclusions drawn within these toxicity summaries are inconsistent and warrant independent assessment. For example:

Diethanolamine
Over 1400L of this chemical will be stored. Tier 2 classification.
- Chronic exposure carries a 'high risk'

- The AECOM Tier 2 report page 236 notes 'limited data available on carcinogenicity'. However, a 2 year study of mice exposed to the chemical showing a marked increase in liver cancer and kidney cancer. AECOM asserts that the 'data on the mode of action are insufficient to conclude that diethanolamine induced tumours are relevant for humans' and therefore they do 'not classify it for carcinogenicity'
- AECOM state there are 'no reproductive toxicity studies available' for the chemical, however, then describe the study that indicates the chemical has the ability to impair reproductive capability. A 90-day study in rats showed it shrink the testicles and prostate of rats, implying it is an endocrine disrupter.

Diethylene Glycol
Tier 2 classification.
- Appendix E 2.0 table 2 Diethylene Glycol is classified as 'low risk based on the acute data'
- A more detailed examination of this chemical on page 242 of Appendix E describes adverse effects on fertility and foetal malformations with significant differences noted between toxicity in rats and people, with people being far more susceptible to poisoning.

Sodium Bromate
Tier 2 classification, 800L stored on site. Appendix E pg. 107
- chemical causes kidney cancer, kidney degeneration, and necrosis (cell death)
- chemical is also noted to cause mutations in bacteria and is proven to be genotoxic (damages DNA)
- 'limited data available on the reproductive or developmental effects' of this chemical
- Despite these findings the assessment is made by AECOM that this chemical is 'not likely to have specific reproductive or developmental effects.

2-Propenoic acid, polymer with sodium phospinate and 2-propenoic acid et al
Tier 2 page 148 of appendix E.
- chemical is stated as 'having no studies available'
- the polymer is not expected to be readily biodegradable due to the very high molecular weight and low water solubility. Due to the high molecular weight the polymer is *not expected* to bioaccumulate
- No data available for chronic toxicity, carcinogenetic, mutagenicity, reproductive toxicity, acute toxicity. There are no aquatic studies on the polymer. The polymer meets the screening criteria for persistence.

The above would seem to indicate a case of making assumptions to enable continued use of suspect chemicals, rather than the use of the precautionary principle. A significantly more thorough independent assessment of the chemical risks of stimulation fluids is required given:

- we now know about the health effects of unconventional gas fields
- these chemicals, as flowback, will sit in open evaporative ponds on site
- these chemicals, as flowback, will be pumped through complicated systems of gathering lines

- the proponent already has a poor track record when it comes to preventing spills
- the proposed drilling site is on a sacred floodplain

D. Lubricants

The lubricant chemical risk assessment also speaks to non-transparent chemical disclosure.

The CAS numbers on 3 of the 7 chemicals used were withheld from AECOM.

Styrene

- classified 'high risk' on the basis of acute and chronic toxicity
- it is not readily biodegradable
- is 'anticipated to be a human carcinogen'
- 'contains a chemical which is a known or suspected reproductive hazard'
- is considered an endocrine disrupter.

The volume to be used, and concentration of this chemical was not disclosed to AECOM. The volumes held on site are not declared in this EMP. No Tier 1 or 2 risk assessments have taken place. All of this renders the chemical risk assessment incomplete.

EvoLube TR

The remaining 3 disclosed lubricant chemicals listed have concentrations and CAS numbers provided. These are triethylene glycol, 2-butoxyethanol and diethanolamine. One would assume these 3 chemicals relate to the product as EvoLube and is comprised of these 3 chemicals. An SDS is provided in the EMP for EvoLube. It is

- 'suspected of causing cancer'
- 'may cause adverse effects on the bone marrow and blood forming system'
- may cause 'adverse liver effects'
- stated that 84% of the product 'consists of unknown hazards to the aquatic environment'
- stated that no information is available as to persistence, degradability, bioaccumulation and mobility in the environment
- Considered an 'acute heath hazard' and a 'chronic health hazard'
- Classified as a 'very toxic material' in Canada.

It is hard to determine from the lubricant recipe whether 14,500 litres or 43,500 litres of the latter 3 chemicals will be held on site. Despite the carcinogenicity and high toxicity or the chemical and the large volumes used, no Tier 2 screen was considered necessary in the AECOM chemical risk assessments.

FLOOD RISK ASSESSMENT

Many of the chemicals discussed above are highly toxic to aquatic life. They will be utilised on a floodplain that feeds and supports a sacred wetland of national and international significance in Longreach Waterhole and Lake Woods. The SREBA documented the ephemeral creek systems of Newcastle Creek as highly significant refuge ecosystems. Flooding increases the risk of accidents on site and of chemical contamination of these waterways. The aquifer water recharged in this region also travels North, underground to support the Roper and Flora (Daly) Rivers and potentially even the Victoria River system.

In the EMP the risk to surface water contamination is classified by Tamboran as 'medium'.[9] In this region surface water becomes groundwater water via sinkhole recharge, so the risk to groundwater contamination should also then be considered 'medium'.

The downstream impact of surface water contamination in the EMP will be felt through the:

- Ephemeral waterholes of Newcastle Creek – identified in the SREBA as being highly ecologically significant refuges
- Longreach Waterhole, and
- The wetland of international significance Lake Woods.

As well as supporting the pastoral industry, many people live, work, play, drink, bathe, hunt, eat, seek medicines, and conduct ceremony in the Newcastle Creek floodplain system.

Floodplain muds are used in many cultural ways that would facilitate chemical exposure if contaminated. Accumulation of heavy metals, persistent chemicals and radiation in muds and food sources, particularly widely consumed shellfish, is a pathway of potential human contamination not adequately considered in this EMP. No heavy metal or chemical residue testing has been conducted on the muds or mussels in the region. Given they are so widely used and are known to bioaccumulate substances including heavy metal and chemical residues, it is critical baseline studies are created, prior to further exploration.

The SREBA Baseline testing parameters for surface water quality are limited to pH, dissolved oxygen, electrical conductivity, and turbidity. The SREBA report recommends future monitoring include heavy metals such as strontium and barium. It is critical this testing is conducted and made publicly available prior to further potential contamination of this watercourse related to the wells proposed in this EMP.

Baselines should be established for any NORMs, carcinogenic or endocrine disrupting chemicals, and bioaccumulating or persistent chemicals, and their breakdown products, prior to commencement of any further fracking.

On page 150 the proponent states "During the wet season, it is likely the broader region could experience widespread periodic surface flooding, to a depth of 300 mm, which has previously been identified by debris being collected on fence lines (HLA, 2005).' Utilising the

[9] Pg 21 PDF EMP https://ehq-production-australia.s3.ap-southeast-

grass on a fence line is not the scientific assessment of a floodplain potential and displays a lack of care and knowledge about the flooding potential of the catchment.

PBR has heard much anecdotal evidence of flood levels of 1974. The area of proposed fracking was inaccessible for months. During that year water ran knee deep through the main street of Tennant Creek. Newcastle Waters Station Homestead was inundated, and the main Street of Elliot was an island with water swirling forcefully all around. Water came up quickly and the rain was unrelenting for weeks.

The Georgina Basin recharge graph in Figure 1 from Department of Water Resources speaks to the massive recharge event of 1974 compared to all other years. Tamboran is grossly underestimating the magnitude of potential flooding in the region and the potential for chemical contamination of waterways, both surface and underground that would result.

Aquifer recharge in this region is largely sinkhole in nature. There is potential for rapid contamination via fast flowing water direct into the aquifer via sinkholes. Lake Woods is also a main recharge point for Georgina Wiso water.

Significant flood events are likely to lead to

- bund walls collapsing (already experienced)
- drill sumps overflowing
- open evaporative ponds overflowing
- tank instability due to erosion on the well pad combined with flooding and cyclonic conditions.

The proposed use of helicopters ‘to transport people and supplies into and out of the site when access is restricted’ is meaningless if there is no ability to land on the site, let alone repair flood damaged infrastructure as water flows through the sites.

- **Recharge** across the plan area varies significantly with precipitation, topography, karstic features, overlying rock and sediment formations.

  Current estimates of total annual diffuse recharge to the Gum Ridge Formation and Anthony Lagoon Formation in the plan area range from about 71 to 230 GL (Tickell and Bruwer 2017; Knapton 2020), the proportion received by each aquifer is uncertain. Modelled recharge to these aquifers is estimated in the range of 0 GL/year – 21,280 GL/year, with a median of 0.5 GL/year and average of 608 GL/year.

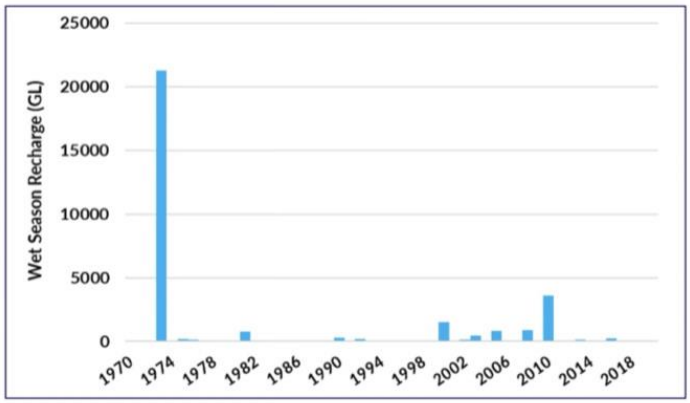


Figure 6. Modelled wet season recharge to the CLA in the Georgina Basin management zone

Figure 1 Recharge Georgina Wiso Plan Area

Traditional Owners recognise that this country becomes one large floodway with extreme weather. The proponent states on page 151 'There are no creeks or stream crossings intersecting proposed site within the Shenandoah South E&A Program, although overland flow and a shallow gully for Shenandoah S B lease pad and Shenandoah N A lease pad will require management actions to divert local water flow around the site.' This does not correlate to the lived experience of elders in the region.

The proponent also advises re Shenandoah N A: 'There is a potential risk from inundation in the 1% AEP from a local catchment flood event. However, this can be managed through moving the lease pad west of its current position to higher ground; or raising the site above the 1% AEP flood level; or increasing diversion drainage along the southern boundary of the site to divert flows around the site.' Here Tamboran seem to acknowledge the risk of well pad flooding, but rather than resolving it by moving the well position, they maintain the position of the well. It is unclear why they would risk flooding in this way.

Table 34, pg. 151 is difficult to conceptualise, but seems to indicate that all sites are only millimetres higher than the flood levels at the nearest channel.

The risk of flooding in this region is significant. Historical accounts tell us it occurs and as climate change progresses, we are seeing increasingly unprecedented rainfalls nationwide. The Territory is no exception. The January floods in the Kimberley should highlight this risk.

The exploration also needs to be seen with reference to the safety of potential production in a full-scale gas play where extensive networks of pipeline would also intersect with this dynamic floodplain.

THREAT OF SURFACE WATER CONTAMINATION FROM DRILL SUMPS

Any risk to surface water and soil contamination ought to be assessed with reference to recent Tamboran operations on the Maverick 1 well pad in 2022/23. This incident and subsequent investigation indicates systemic problems in monitoring, testing and public disclosure that is designed to protect the public and environment from chemical contamination. In summary:

- Over 300,000 litres of contaminated drill sump water was illegally used as a dust suppressant on the Maverick 1 well pad
- Tamboran claimed the wastewater use was accidental, however whistle-blowers have alleged the act was deliberate
- The company was initially fined $6000 for the accidental spill. This fine appears not to have been increased upon the disclosure of deliberate act
- PBR contacted the EPA to ascertain how the investigation would progress given the spill now seemed deliberate and was informed 'the NT EPA does not regulate onshore fracking activities'
- PBR requested information from the regulator as to the chemical composition of the wastewater and was informed 'The Department is unable to comment on the quality of onsite wastewater prior to September 2022 as no sampling had been conducted by the department at this time'
- Belated soil sample test results were taken from the well pad. PBR requested copies of results from the Department and were directed to lodge a freedom of information request to obtain the results
- Prior to soil testing taking place a poorly constructed bund wall broke during wet season rain presumably allowing the drill sump water contaminants to flow into the Newcastle Creek/Lake Woods catchment
- During a 2023 minor flood event Tamboran were found to have pumped toxic wastewater onto a cattle breeding paddock on Tanumbirini Station. This is now*.* subject to an EPA investigation; no results of the findings have been released.

The implications of extrapolating these types of 'accidents' across more well pads in the Lake Woods catchment needs to be considered by the Minister and the risk to surface and ground water be re-examined In light of this incident, it is critical that drill cutting, sump and sump water is tested immediately on return to surface and that these results are made available to the public in real time.

The proponent plans to use previous Amungee Wells NORM values to determine the radiation risk of these wells. This is unacceptable given uranium and other radioactive material are widespread across the NT landscape. Each wells drill cut should be assessed for individual radiation risk, heavy metal and chemical risk.

FAUNA PROTECTION

Critical to ecosystem protection from fracking is protection of fauna, both aquatic and terrestrial from exposure to chemical pathways highlighted in the Haswell Report. All mammalian systems are likely to suffer similar fates if exposed to these chemicals. All other

fauna will be affected in various and unpredictable ways. For Aboriginal members of PBR the potential contamination of fauna is a pathway for human contamination via ingestion as well as having spiritual ramifications linked to totem.

The Pepper Inquiry recommended that the SREBA into terrestrial ecosystems '*must establish sampling methods for that group, that provide sufficiently high detection probability for robust analysis of geographic patterns and detection of change in community composition over time.'* Unfortunately, the sample timeframe was conducted over 2 very poor wet seasons.

In photographs Figure 2 & 3 below, taken across 2 wet seasons at Newcastle Creek crossing, heading into Marlinja Community, the district differences in bird populations are evident. The SREBA studies across 2 poor wet seasons therefore cannot be reliable baselines for population decline related to onshore gas and they will significantly underrepresent the populations that can be present in the ecosystem.

In addition, the SREBA surveys were meant to occur late dry and late wet. However, Covid and access problems meant often survey areas were only visited once so assessing seasonal variation was not possible.

For aquatic species Pepper stated:

The Inquiry notes the high inter-annual variability in aquatic systems in the Northern Territory, as well as additional unpredictability in wetting-drying cycles in arid and semi-arid regions, and therefore that multi-year sampling is important. SREBA Guideline Page 4

Accordingly, it is essential that any SREBA is designed to include multiple-year sampling of aquatic ecosystems. As a general rule in the Top end two to five years of baseline data will be required achieve adequate coverage of inter-annual variability,[35] while in drier zones a longer timeframe is required. Chapter 15 Pepper

Unfortunately, the SREBA field work for aquatic biodiversity surveys was confined to the dry season due to the difficulty of accessing survey sites during the wet. Sampling occurred throughout two dry seasons only. Survey sites were visited only on one occasion, so there is no seasonal data.

Without meaningful seasonal population data trends, or baseline data, there is no ability to detect declines in endangered and threatened species populations. Many of the chemicals used in this EMP are potential endocrine disrupters. Their potential effects on reproduction of various species may slow to become apparent.

In the EMP animal the proponent advises fauna interactions with wastewater will be recorded daily during operations. A trigger >7 per week for two (2) consecutive weeks or >1 threatened fauna species is applied. It is unclear if this means dead animals, or animal seen drinking from or cooling in the various ponds on site.

Figure 2 Marlinja good wet season May 2023,



Figure 3 Marlinja poor wet season January 2024, same location



CONCLUSION

There are many more concerns that PBR have about this EMP which we do not have ample time to elaborate on including but not limited to:

- climate implications of new gas fields in an area where the reality of climate change is already forcing many to leave our community, eroding the fabric of our towns
- aquifer integrity related to fragile karstic structures
- the potential loss of Stygofauna
- the potential interconnectivity of aquifers may permit fracking fluid migration and aquifer or surface spring water contamination

This EMP represents a move towards full scale shale gas production, with 'beneficial use' of the gas proposed within the EMP. The expansion of 19 new wells and 5 well pads carries with it significant cumulative environmental and cultural risk to our region.

As a minimum, it is time to refer these projects to the EPA for full assessment.

[redacted]

From: Melissa Haswell <melissa.haswell@sydney.edu.au>
Sent: Wednesday, 10 January 2024 12:02 AM
To: tamboran DEPWS
Subject: Fw: Submission to the Petroleum Environmental Management Plan Tambourin B2 Pty Ltd
Attachments: EMP Tamboran submission Jan 2024.pdf; health risks of oil and gas report 2023.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Madam/Sir,

Please see attached a Submission to the EMP of Tamboran B2 Pty Ltd to undertake exploratory drilling and fracking in the Beetaloo Basin. We also attach a copy of our recent report entitled, *The risks of oil and gas development for human health and wellbeing: a synthesis of evidence and implications for Australia.* This report is extremely relevant for any considerations of progressing oil and gas expansion in Australia.

We would like these documents to be included in the public submissions for consideration of the EMP.

We will be happy to present our information at any hearings associated with the EMP and provide any further evidenced based information on request.

Many thanks

Melissa Haswell

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The University of Sydney's campuses and facilities sit on the ancestral lands of the Gadigal, Gamaraygal, Dharug, Wangal, Darkinyung, Guringgai, Gamilaraay, Barkindji, Bandjalang, Wiradjuri, Darkinyung, Ngunawal, Gureng Gureng and Gagudju peoples, who have for thousands of generations exchanged knowledge for the benefit of all.

I also acknowledge the Jinibara peoples of the Mt. Nebo region upon whose ancestral lands my work is frequently conducted.

Submission on the Petroleum Environmental Management Plan Tamboran B2 Pty Ltd to undertake exploratory drilling and fracking in the Beetaloo Basin, Northern Territory

Prepared by Professor Melissa Haswell BA, MSc, PhD (Epidemiology)[1] and Emeritus Professor Dr David Shearman AM MB, ChB, PhD, FRACP, FRCPE[2]

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[2] Emeritus Professor of Medicine, Adelaide University

The authors acknowledge that this work was prepared on the Lands of the Jinibara People (in Queensland) and the Peramangk and Kaurna Peoples (in South Australia). We pay deepest respects to their Elders past and present. We also acknowledge the Traditional Custodians of the Lands that would be directly affected by the planned exploration drilling. We pay deepest respects to their Elders past and present, reflecting on their loving care and nurturance of these Lands for many tens of thousands of years.

Bios of the Authors

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Professor Haswell holds a Master of Science (University of North Carolina) and a PhD and Diploma from Imperial College of Science and Technology, University of London. Professor Haswell has taught undergraduate and post-graduate students in medicine, public health, Aboriginal health and environmental health for 25 years at University of Queensland, University of New South Wales, Queensland University of Technology and University of Sydney. Professor Haswell has authored over 90 peer-reviewed publications based on research in the fields of Aboriginal and Torres Strait Islander and environmental health, infectious disease epidemiology and control, carcinogenesis, environmental toxicology, psychosocial and community empowerment and mental, social and emotional wellbeing.

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David Shearman is Emeritus Professor of Medicine at Adelaide University and previously held senior positions at Edinburgh and Yale Universities. He has authored many books on climate change, its science, consequences and democratic, international and economic implications. He served on the IPCC for two terms on health and scientific sections. He was President of Conservation Council of South Australia and, with the late Professor Tony McMichael, he founded Doctors for the Environment Australia in 2001, serving as Honorary Secretary from 2001 to 2018. He is author and co-author of several hundred scientific and medical papers and writes frequently for the media. He was appointed a Member of the Order of Australia (AM) in 2015 for his service to medicine and to climate change.

Executive Summary

The authors of this submission have been immersed in the global scientific and medical literature regarding shale gas and oil operations for over a decade. We write multiple submissions, reports and media articles from evidenced knowledge of how this industry has negatively impacted millions of people within a short time period. We find an absence of information confirming its long-term safety and benefit to residents of areas where the industry moves in. We recently completed a comprehensive review and synthesis of evidence on the risks of the industry to human health and wellbeing, available here. We draw heavily on this evidence for this submission, as we identify the potential implications for the people and environment of the area covering the Beetaloo Basin.

This submission concludes that a comprehensive and detailed review of the environmental health implications and improvement of the Environment Management Plan (EMP) drafted by Tamboran B2 Pty Ltd to mitigate these risks is required on multiple grounds, including significant risks to the health and wellbeing of people directly affected by the exploratory operations, as well as those that may be indirectly affected by associated activities. We conclude the EMP does not adequately consider substantial evidence regarding:

1. Cultural, spiritual and social disturbances and distress associated with environmental impacts of the activities to be undertaken, especially to Traditional Custodians,
2. Chemical contamination by naturally occurring chemicals in fluid present in the shale layer, the complex mixtures of chemicals, low concentration endocrine disrupting chemicals and airborne contaminants and the many migration pathways and likelihood of these chemicals moving into the environment leading to exposure to humans, livestock and wildlife,
3. Physical health risks associated with shale oil and gas operations that may be experienced by people living in nearby communities.

There are other issues of extreme concern not included here due to time constraints. This includes the potential impacts of excessive withdrawal of water from aquifers that play a vital role in maintaining life, including human life, in the region. In addition, of great importance is the contribution of the proposed activities to greenhouse gas emissions, including methane, ground level ozone and carbon dioxide that these exploration activities and subsequent activities would release. The consequences of 'off-the-scale' ocean and surface temperatures and sea ice loss, combined with steep upward trends of both CO_2 and methane concentrations in the atmosphere over the last 12 months are yet to be understood. However, they reflect the absolute urgency of moving away now from any new fossil fuel developments to preserve our health, environment and survival. The EMP provides an unrealistic and unsubstantiated assessment of the ability of the proposed partial offsets to significantly abate the significant fugitive and stationary energy emissions that would be released from the proposed activities.

As the research literature in these areas has grown rapidly in both quality and quantity in the last five years, the Pepper Inquiry of 2017/2018 does not consider the substantial new body of evidence on the health impacts of oil and gas operations and is now significantly out of date and not a true representation of current knowledge of the risks of the industry. The SREBA report health section was also incomplete, missed many studies published between 2018 and 2022 and does not accurately reflect current knowledge.

In its 637-page Compendium (ninth edition), the Physicians for Social Responsibility, the Concerned Health Professionals of NY and the Science and Environmental Health Network in the United States concluded once again that "**Our examination uncovered no evidence that fracking can be practiced**

in a manner that does not threaten human health directly or without imperilling climate stability upon which human health depends".

We believe all Australians, wherever they live, deserve the same scrutiny and state and territory governments must provide this in their decision making. We urge the NT government to demand a comprehensive and detailed review of the environmental health risks and implications and improvement of the Environment Management Plan (EMP) drafted by Tamboran B2 Pty Ltd to mitigate these risks before any further progression of these activities are allowed and NT residents are put at risk. Towards this end, we have prepared this submission which summarises the evidence in some key areas, we attach our 2023 full synthesis report with more detail and provide multiple appendices with extensive lists of relevant references to enable assessors to understand the gravity and strength of evidence of issues raised. We argue that these resources, and the Compendium mentioned above, must be reviewed by decision makers to make a fair and accurate assessment of how local and regional populations and all Australians may be impacted by both exploration activities and movement towards full scale fracking.

We now provide a brief overview of the three concerns about the EMP addressed in this Submission.

Concern 1. Cultural, spiritual and social disturbances and distress associated with the environmental impacts of the activities to be undertaken, especially to Traditional Custodians, are not adequately considered.

> ***A proper risk assessment or health impact assessment informing an Environmental Management Plan must first consider the environmental impacts as experienced by the people who are most likely to be affected by a development. The EMP does not do this, it considers the environment in isolation of the deep attachment of people to the environment and harms resulting from emotional, financial, psychological, social, cultural and spiritual turmoil and the particular risks to women and children are largely ignored.***

The Petroleum EMP prepared by the oil and gas company, Tamboran, proposes to undertake extensive exploratory shale gas drilling and hydraulic fracturing in the Beetaloo Basin, which lies between Katherine and Tennant Creek, about 500 kms south of Darwin in the Northern Territory. Other towns in the region include Borroloola, Elliott, Marlinja, Mataranka, Beswick, Barunga, Ngukurr, Jilkminggan, Daly Waters, Minjerri and Larrimah.

The obvious purpose of this exploration activity is to provide information to guide a well-publicised plan to develop extensive shale oil and gas production, which has been referred to as 'the Marcellus of Australia' and the 'hottest play on the planet", within the Beetaloo Basin. This reference points to the massive size and the mixtures of oil and gas within the Basin that, if developed, would require a massive industrialisation of the region on a scale that is difficult to imagine – and easy to conceal in discussions with landholders. Such a development would completely change the region from its current, relatively pristine state protected by tens of thousands of years of care and nurture by Aboriginal peoples.

These communities and interspersed areas covering the Beetaloo Basin have been the homelands of many clan groups since time immemorial, including the Garrwa, Yanyuwa, Marra and Gurdanji, the Jawoyn, Alawa, Jingili, Walmanpa, Warumungu, Ngandji and Binbinga and many others, as well as people those living downstream from planned drilling activities, including the Mudburra, Garrwa, Yanyuwa and Gurdanji.

These Traditional Owners are descendants of countless generations of custodians whose love for their Lands and waters have sustained unique ecologies and timeless cultural and spiritual traditions. Among these are strong responsibilities of ecological protection and caring to be passed on to future generations to thrive, enjoy and care for. Like Indigenous Peoples all over the world, many are suffering disproportionately from ecological degradation outside their control, resulting from poor water management, pollution and soil salination, deforestation, spread of invasive species, mining and global heating driving unprecedented droughts, bushfires and torrential rains, etc. (UN Environment Program, 2020; HEAL and CRE-STRIDE, 2021; Cresswell et al., 2021; Standen et al., 2022; Matthews et al., 2023). This damage is identified as a grave concern requiring real partnership with Aboriginal and Torres Strait Islander people to address in Australia's State of the Environment report 2021 (Cresswell et al., 2021; https://soe.dcceew.gov.au/).

There is substantial evidence (reviewed in Section 2 and 5.2 in Haswell, Hegedus & Shearman, 2023, references listed in Appendix 1) linking complex shale gas and oil operations to **all of these ecological and social harms**. With the rapid proliferation of many wells across wide areas, the enormous water footprint ranging from extensive ground water extraction from the environment and risks resulting from wastewater handling and the large fly-in fly-out and trucking workforces, shale oil and gas operations carry an enormous potential to contaminate and degrade vast tracts of land and associated biodiversities, change the social, cultural and physical character of settlements and communities and plunge residents into social, emotional, financial, psychological, cultural and spiritual turmoil.

Many Aboriginal people from these clans have spoken out against the proposed industrial transformation, making it very clear that the damage inflicted on the environment is felt as if the damage was to a relative or directly onto oneself (Reviewed in Section 5.3, Haswell et al., 2023, References listed in Appendix 2).

The severe loss of safety of First Nations women and children from sexual assault, as evidenced in multiple documents in the United States and Canada (Section 5.4) has been ignored in all documentation regarding the Beetaloo Basin, despite many similarities in circumstances that could be created by FIFO workers and vast truck movements in and out of the region. The Landmark report, "Enough is Enough" emerging from the West Australian Inquiry into sexual harassment against women in the FIFO minding industry reported "a staggering range of abuse, harassment and assault". This repeated oversight suggests that preparations or additional protections have not been taken seriously and made available to ensure the safety of women and children living remotely near to the oil and gas operations.

The Australian State of the Environment report 2021 states clearly, "The general outlook for our environment is deteriorating … [due to] pressures from climate change, habitat loss, invasive species, pollution and resource extraction". It also states the "Environmental decline affects the wellbeing of all Australians, noting that "Our health, living standards, cultural and spiritual fulfilment, and connection to Country are all inextricably linked to our environment" (Cresswell et al., 2021).

These evidenced potential harms to the environment from the proposed drilling and fracking threaten the social, emotional, spiritual and cultural wellbeing of people living locally in the areas where this project is proposed and require a comprehensive and detailed review of the environmental health implications and improvement of the EMP to mitigate these known risks. These cannot be ignored in a full and proper assessment of the environmental risks. A bias against social, spiritual, cultural and mental health risks is no justification for ignoring them and their likely consequences given the large body of knowledge now accumulated.

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Concern 2. Chemical contamination by naturally occurring chemicals or mixtures, especially low concentration endocrine disrupting chemicals and airborne contaminants and the many migration pathways and high likelihood of these chemicals into the environment leading to exposure to humans as well as livestock and wildlife are not adequately considered in the EMP.

> ***The information provided in the EMP on potential chemical contamination of the environment is large (lots of pages) but unprocessed, not aligned with conditions for example of salinity, temperature or pH and not assessed with concern for mixtures of chemicals. Very importantly the EMP does not consider naturally occurring chemicals present in the shale that are brought up in the wastewater which would otherwise be safely retained underground. The incomplete way that these assessments have been done provides little confidence that the company is aware of, or particularly concerned about, the dangerous potential impacts of the extensive chemical cocktails that their workforce will be handling in likely very large quantities. Spills, leaks, overflows and deliberate releases of wastewater can and do occur with negative environmental impacts as clearly evidenced in the literature. Without such awareness shown in their management plan with tailored prevention and monitoring strategies and clearly defined remedial responses should contamination occur, the assurance of safety of land and water resources, directly employed and contracted workforces and surrounding properties and communities is not affirmed.***

The water and air quality implications of shale oil and gas operations are substantial. Our report summarises a large volume of literature examining the chemicals of concern in both the added drilling and fracking fluids as well as the naturally occurring chemicals which have been formed and

present, sometimes in high concentrations, for millions of years (Section 4, Haswell, Hegedus and Shearman, 2023). The report also highlights some of the pathways of movement of chemicals from the site of operations into the environment that have been identified in other countries where the industry is comparatively mature and research undertaken. Its references are listed in Appendix 3 for follow up examination by the EMP review committee.

Each year, the Physicians for Social Responsibility, the Concerned Health Professionals of NY and the Science and Environmental Health Network updates its *Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure*. Now in its ninth edition (October 2023) and 637 single space pages, the Compendium cites case after case of investigated environmental contaminations of fracking and naturally occurring chemicals found in ground and surface waters, in the air and increasingly in food irrigated with oil and gas wastewater. This document, available at https://concernedhealthny.org/wp-content/uploads/2023/10/CHPNY-Fracking-Science-Compendium-9.pdf, leaves no doubt that chemicals added and those naturally occurring, but brought to the surface from oil and gas activities, can and do enter the environment.

To summarise, multiple inventory lists of these complex chemical mixtures (which may not cover all chemicals actually used or naturally occurring in wastewater) include:

- many possible, probable and known cancer-causing chemicals (carcinogens),
- many that directly damage tissue and organs in the body (toxins),
- many known to harm the reproductive system (reproductive toxins),
- many that interfere with normal human development, including those capable of causing birth defects (teratogens) and impairing development of the brain and nervous system (neurodevelopmental toxins), and
- many that interfere with metabolism through disruption of endocrine system (endocrine disrupting chemicals).

PAHs, heavy metals, naturally-occurring radioactive materials (NORMs) and a wide array of known and unknown chemicals used in drilling and hydraulic fracturing fluid have the potential to damage the health of workers and community residents who may be exposed through contact with water that has been contaminated during the handling of the large quantities of chemicals and wastewater involved (Esswein et al., 2014). Radioactive materials, such as uranium, thorium, radium and their decay products, can be found in unconventional gas wastewater and are concentrated and brought to the surface during extraction and waste disposal (US EPA, 2018). If these technologically enhanced naturally occurring radioactive materials, or TENORMS, are present at sufficient levels, workers and nearby residents may be at risk of exposure through air and water (Esswein et al., 2014; Geltman and LeClair, 2018; US Environmental Protection Agency, 2023).

Volatile organic compounds, including BTEX (benzene, toluene, ethylene and xylene), which occur naturally in shale, can contaminate groundwater and enter the atmosphere from the flowback wastewater after fracking and during flaring of excess gas. Benzene contamination of groundwater was a frequent consequence of 77 surface spills that were reported in a 12-month period in a Colorado county with intense shale gas mining activity (Gross et al., 2013).

Elliott et al. (2017a) looked at the reproductive and developmental toxicity of 1021 chemicals identified in fracturing fluid, wastewater or both. Information on toxicity was lacking for 781 (76%). Among the 240 that had been evaluated, 103 were known to have the potential for reproductive toxicity and 95 for developmental toxicity. Webb et al. (2018) reported numerous neurodevelopmental and neurological effects of many chemicals associated with gas operations, focussing particularly on risks to children. Some of these developmental impacts are likely to be mediated by endocrine disrupting chemicals.

Evidence of endocrine-disrupting activity in surface and groundwater in areas with unconventional gas mining raises significant concern (Kassotis et al., 2014; 2016a; 2016b; 2016c; 2018a; 2018b; 2019a; 2019b; 2020; He et al.; 2018) because these chemicals can interfere with endocrine function at very low concentrations, sometimes without overt signs or symptoms. emissions from oil and gas mining operations have a real potential to expose humans, livestock and wildlife to a wide range of chemicals with endocrine disrupting activity through contamination of both air and water. Balise et al. (2016) reviewed 45 peer-reviewed publications that examine links between conventional gas extraction processes and the presence and potential impacts of endocrine-disrupting activity. They found moderate evidence of an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer that could result from disruption of the oestrogen, androgen, and progesterone receptors by chemicals associated with (mostly conventional) oil and gas production. Despite the rapidly growing literature in the United States on these chemicals, as well as recent experiences across Australia with one family of EDCs, namely PFAS, they have rarely even been mentioned in risk assessments and documents guiding decision-making on gas production expansion in the country, and very few Australians understand the serious threat of these chemicals to human health. We observe no indication in the EMP that these are recognised by the proponent company.

Foetuses (through their pregnant mother's bloodstream), infants (through inhalation, drinking and through their mother's breastmilk), children, elderly people and people with chronic illnesses are often the most at risk from these chemicals. The reasons for this vulnerability are complex and include increased exposure due to age-specific behaviours, sensitivity associated with developmental stages especially in utero and the additional stress put on already impaired organs and systems due to age or disease.

The combination of some of these chemicals and their resulting by-products can also accumulate and persistent indefinitely in the environment or be taken up and concentrated by plants and animals and ultimately enter the food chain.

The observation of multiple health impacts observed in and near many gas basins across the United States, with varying geographies, geologies, chemistries, policy and regulatory environments discussed below (Concern 3) especially those occurring more frequently downstream in groundwater or upwind blowing contaminants from the operations into the living environment is a powerful indicator that current operations **<u>are not preventing</u>** human exposures and detrimental impacts.

Based on the literature briefly described here, more extensively in our report (Haswell et al., 2023) and papers listed in Appendix 3, it is clear that a comprehensive and detailed review of the environmental health implications and improvement of the Environment Management Plan (EMP) to mitigate these risks is required to correct the errors, gaps and assumptions made in the preparation of this EMP. This must reflect the current state of knowledge about these chemicals as well as demonstrating awareness and precautionary steps taken given the potentially severe unknowns and uncertainties.

Concern 3. There is no attention to the now well-established and serious physical health risks associated with shale oil and gas operations among people living in impacted areas.

> ***We are very concerned that the EMP does not identify or address the now well-established health risks associated with all steps of gas and oil operations. Over the past decade, as the industry has continued to spread across the United States, the evidence of serious health and foetal development harms associated with industry activities and infrastructure has also grown in both quality and quantity. Increased incidence and hospitalisation for diseases of the heart, respiratory, reproductive and nervous systems, of childhood cancers and of birth abnormalities living nearby, especially upwind or downstream in groundwater, are telltale signs that people have experienced additional exposures to chemicals in their environment and to excessive levels of stress. Similar to the lack of attention to or apparent knowledge of the chemical and psychosocial and cultural risks in the EMP identified in Concern 1 and 2, the inadequate consideration of health impacts suggests that steps are not likely to be taken to appropriately monitor or mitigate these risks.***

A large number of studies have now reported health effects among children and adults living in proximity to oil and gas operations that may result from both chemical exposures and chronic distress. These are discussed in our Report (Haswell et al., 2023, Section 5.1) and peer-reviewed references are listed in Appendix 4.

Briefly, these health effects include:

- Symptoms and markers of disease: migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, asthma exacerbation requiring medication changes and cardiovascular disease indicators (McCarron, 2013; Rabinowicz et al., 2015, Rasmussen et al., 2016; Tustin et al., 2017, McKenzie et al., 2019; Blinn et al., 2020; Weisner et al., 2023).
- Higher hospitalisation rates among adults for heart disease, including heart attacks and heart failure; for respiratory and neurological disorders; for those with existing asthma conditions (emergency department visits, inpatient stays); and for some childhood cancers and immune deficiency disorders (Rasmussen et al., 2016; Jemielita et al., 2015; Werner et al., 2017; Whitworth et al., 2018; McCarron, 2018; McKenzie et al., 2017; McAlexander et al., 2020; Blinn et al., 2020; Denham et al., 2021; Blundell and Kokoza, 2022; Buonocore et al., 2023).
- Asthma exacerbations and hospitalisations among children (Willis et al., 2018; 2020; Bushong et al., 2020; Buonocore et al., 2023).
- Increased deaths and reduced life expectancy from cardiovascular and respiratory diseases and some cancers (Denham et al., 2021) and from all causes (Apergis et al., 2021; Li et al., 2022; Buonocore et al., 2023).
- Higher incidence of childhood blood cancers, especially acute lymphoblastic leukemia (Werner et al., 2016; 2018; McKenzie et al., 2017; Clark et al., 2022).
- More frequent traffic and pedestrian injuries and fatalities (Retzer et al., 2013; Graham et al., 2015; Blair et al 2018; Xu and Xu, 2020).

The following findings relating to psychological and social stressors are discussed in Concern 1:

- Higher incidence of mental health conditions: depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022) and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females seeking treatment in Pennsylvania (Gorski-Steiner et al., 2022).

- Increased incidence of sexually transmitted infections such as chlamydia and gonorrhoea, resulting from changes in sexual behaviour that can be associated with an influx of mobile workers in depressed areas (Mabey and Mayaud, 1997; Komarek and Cseh, 2017; Deziel et al., 2018).

Three conditions of pregnancy that can affect birth outcomes have been shown more frequently in pregnant women living closer to active gas well, namely antenatal depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022), hypertension (5% increase) and pre-eclampsia (26% increase) (Willis et al., 2022).

Reported negative birth outcomes include:

- Reduced average birth weight and small for gestational age (Stacy et al., 2015; Currie et al., 2017; Hill, 2018; Deziel et al., 2020; Hill and Ma, 2020; Tran et al., 2020; Willis et al., 2020; Caron-Beaudoin et al., 2021; Cairncross et al., 2022);
- Higher incidence of low-birthweight babies (Currie et al., 2017; Hill, 2018; Hill and Ma, 2020);
- Higher frequency of pre-term and extreme pre-term deliveries and spontaneous abortions (Casey et al., 2016; Hill et al., 2018; Whitworth et al., 2018; Cushing et al., 2020; Deziel et al., 2020; Hill and Ma, 2020; Gonzales et al., 2020; Caron- Beaudoin et al., 2021);
- Birth defects, including congenital heart valve defects, anencephaly, spina bifida and gastroschisis (McKenzie et al., 2014; Janitz et al., 2019; Tang et al., 2021; Cairncross et al., 2022; Willis et al., 2023; Gaughan et al., 2023; Han et al., 2023);

As a body of research, this evidence provides a compelling case for direct harms of the oil and gas industry across the lifespan on individuals – from foetal development to infancy and childhood, to young and pregnant women to adulthood and elderhood. Pre-birth and childhood impacts, and impacts on mothers, fathers and extended family members, can have whole of life consequences.

The complex diversity of chemicals and modes, timing and patterns of possible exposures and the added influence of varying social, emotional, economic and spiritual stressors would be expected to produce a diversity of findings and outcomes across studies. With Australia's substantially smaller pool of public health researchers and resources, it is difficult to imagine research of this scale and magnitude to be possible to reveal how communities are impacted should a major American-style industry be established here.

Three outstanding studies have substantially increased our understanding of all-cause mortality (7500 premature deaths) and the enormous health losses and economic costs (AUS$103 billion dollars per year) associated with air pollutant emissions from a mature oil and gas industry (Li et al., 2022; Apergis et al., 2021; Buonocore et al., 2023). While morbidity and mortality are higher in heavily developed oil and gas regions, the analysis also demonstrated the spread of ozone, PM2.5 and oxides of nitrogen from these regions to others, including into neighbouring states. Another critical factor not included is morbidity due to deteriorating mental health, which has been less extensively studied.

> ***As the evidence of these health effects has grown substantially since the Pepper Inquiry and are not covered in the SREBA Health report, we urge a comprehensive and detailed review of the health implications and improvement of the Environment Management Plan (EMP) to be undertaken to investigate and eliminate the causative environmental health risks fully before any exploration activities commence.***

In conclusion, this Submission adds to many documents we have submitted since 2016 in attempts to help the Northern Territory government recognise the serious direct and indirect health and wellbeing risks that shale oil and gas operations bring to people and the world. We have consistently taken the time to compile the rigorous evidence emerging from health research on gas mining to ensure that, when making decisions about its future, **the NT government is provided with clear access to the large body of evidence documenting many serious concerns and losses to health and wellbeing of people, the environment and the climate.** We hope that the information provided in this submission will be taken seriously and support the government's decision making in favour of the health and wellbeing of Northern Territorians.

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[redacted]

From: Stephanie Booker <stephanie@lockthegate.org.au>
Sent: Monday, 8 January 2024 3:06 PM
To: tamboran DEPWS
Cc: George Woods
Subject: Lock the Gate's submission to consultation on Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan
Attachments: 240108 LtG TAMI 1-1 submission .pdf; Attachment A - Soeder Geo Beetaloo report.pdf; Attachment B - Currell Report on Shenandoah South EA Program.pdf

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Hello,

Please find attached Lock the Gate's submission to the NT Government consultation on Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan, on behalf of George Woods.

Kind regards,

Steph Booker
Legal Coordinator
Lock the Gate Alliance

LOCK THE GATE ALLIANCE
AUSTRALIANS WORKING TOGETHER TO PROTECT OUR LAND, WATER, AND FUTURE

Reply to: Georgina Woods
Head of Research and Investigations
george@lockthegate.org.au

8 January 2024

Department of Environment, Parks and Water Security
Petroleum Operations Unit
By email: TAM1.EP98+117@nt.gov.au

Objection: Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

Introduction

Thank you for the opportunity to comment on the Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan (the EMP).

The Lock the Gate Alliance is a national collection of grassroots organisations made up of over 120,000 supporters and hundreds of local groups concerned about risky coal mining, coal seam gas and fracking. Several of these groups are located in Darwin, Katherine and Alice Springs, as well as rural and remote areas around the NT. Our members include farmers, traditional custodians, conservationists and urban residents. Together, we have a vision of healthy, empowered communities that have fair, democratic processes available to them to care for their land and water.

There has been serious deficiency in community consultation for this proposal. Statutory timeframes constrain the discretion of the Minister and Department from allowing the public and affected communities, including Traditional Owners and Native Title Holders, a reasonable opportunity to read, respond and engage with over 3,600 pages of material during only 28 calendar days covering Christmas and New Year.

This is an action with the potential to have a significant environmental impact on the environment within the meaning of s 11 of the *Environment Protection Act 2019.* The significance of its impact arises from the context and intensity of the impact (being the amalgamation of five existing EMPs and the creation of 15 new wells in the Beetaloo Basin). It also arises from the sensitivity, value and quality of the environment impacted on, and the duration, magnitude and geographical extent of the impact. This will be set out below. The action therefore requires referral to the Environment Protection Agency (EPA) under s 50 of the *Environment Protection Act 2019*. The proponent has self assessed that its actions will not have a significant impact on the environment, despite the potential its activities will significantly impact the environment. It is therefore incumbent upon you to refuse to consider the application until the action is referred to the NT EPA and a decision is made on referral.

The activity in any case will have an unacceptable impact on the environment and people of the Northern Territory and must be refused. Lock the Gate Alliance objects to this project for its unacceptable impacts on the environment and people of the Northern Territory, as described in the submission below.

With this submission we attach two expert reports: Attachment A is a review of Shale Gas Drilling with the Helmerich & Payne Flex 3 Rig in the Beetaloo Basin, Northern Territory, Australia by Daniel J. Soeder; Attachment B is "Environment Management Plan for the Shenandoah South E&A Program: Potential environmental risks associated with proposed shale gas exploration and appraisal program" by Prof Matthew Currell.

Summary

Tamboran concedes in the EMP that "Exploration activities are an essential step in defining a potential future commercial resource" (section 2.1). While willing to claim the purportedly "sustainable, long-term benefits to the local community, to the Barkly region generally and more broadly into the rest of the NT," (page 35) of the full-scale production for which this project is "essential," the EMP does not engage with the profound inter-generational inequity of exploiting this resource, and its climate change implications for communities, wildlife and businesses in the Territory for generations to come. You must take this into account when assessing whether you are "reasonably satisfied" that the EMP meets the approval criteria in regulation 9. As per regulation 9, you must be reasonably satisfied that the EMP contains all information required in Schedule 1, including, per clause 3(1), details of all environmental impacts and environmental risks of the regulated activity described in the EMP, and an assessment of those impacts and risks. "Environment" is defined broadly - in s6 of the *EP Act 2019*, environment means "*all aspects of the surroundings of humans including physical, biological, economic, cultural and social aspects*."

This activity will have a significant impact on the environment and requires referral to EPA for assessment. Some of these significant impacts are described in the submission below and include emission of a large volume of greenhouse gas emissions, potentially increasing Territory annual emissions by nearly 3.5% and significant risk of pollution of ground and surface water, including the nationally significant wetland Lake Woods downstream.

The proponent's EMP has failed to meet the approval criteria in section 9 of the *Petroleum (Environment) Regulation 2016* (*PER*) on a number of counts, including:

- It provides incomplete and inaccurate information about its emissions of greenhouse gases. The estimate of 400,000 tonnes of greenhouse emissions over four years cannot be relied upon by the decision-maker in assessing this application because it relies on a "flare avoidance program" that is not part of this EMP application and may be determined by the proponent to be too expensive to pursue. In its third year of operation, emissions could be as high as 490,575 tonnes, increasing the Territory's annual emissions by 3.4%.
- Furthermore, the proponent's emissions estimates from flaring relies on outdated methods and may be under-estimated.
- The proponent invokes lifecycle greenhouse emissions benefits of gas as a replacement for coal power in undisclosed locations, but does not include assessment of lifecycle emissions

from the project, including emissions from sand mining for proppant, transportation to Queensland of waste materials, and downstream use of the gas if beneficial use is pursued.

- The EMP fails to meet approval criteria because it provides incomplete information on water resources as detailed in the submission and the attached advice from Professor Matthew Currell.
- The EMP similarly fails to collect and present necessary and adequate data to describe and assess the impact of the activity on biodiversity.
- The EMP as exhibited does not, under criteria s 9(1)(c) "demonstrate that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is (i) as low as reasonably practicable or (ii) acceptable."
- Specifically, the EMP fails to meet approval criteria to reduce risks to as low as reasonably practicable (ALARP) or to a level that is acceptable in, for example, the management of fracking wastewater and the management of greenhouse gas emissions, as detailed in the submission.

There are several instances where the requirements of the *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (the Code of Practice) are not met, particularly with respect to:

- the discharge of wastewater and the use of open storages of wastewater;
- the requirement for six months of baseline data to be established from groundwater monitoring bores prior to drilling commencing;
- the requirement for "an auditable chain of custody system" for wastewater tracking; and
- the requirement for the EMP to include, where onsite disposal of drill cuttings is proposed; "certification from a suitably qualified third party that the material is of acceptable quality for disposal to land by the proposed method."

Furthermore, the proponent relies on the Code of Practice and the Fracking Inquiry recommendations for its claim to have reduced impacts to an acceptable or ALARP level, despite several crucial recommendations from that Inquiry remaining unmet.

Finally, the record of the proponent's recent activities in the region is a relevant consideration for this EMP. There is a considerable list of spills, leaks and failures of reporting, equipment and systems in the recent history of the proponent's activities that indicate that the risks of contamination of the environment from waste water, chemicals and other environmental risks are not reduced to as low as reasonably practicable.

The EMP as exhibited indicates that this project is contrary to the principles of Ecologically Sustainable Development, particularly the principles of intergenerational equity, improved valuation, wise use of natural resources and the precautionary principle. Further detail is provided in the submission.

We note that the proponent has not, to date, referred this project to the Commonwealth as a controlled action under the *Environment Protection and Biodiversity Conservation Act (EPBC Act)*. On the information provided in the EMP, it is clear that the project should be declared a controlled

action for its likely or potentially significant impacts on matters of national environmental significance, including nationally listed threatened species, and water resources.

Given the time constraints in making this submission responding to over 3,600 pages of material in 28 calendar days covering the Christmas and New Year period and your own shut down period, we are concerned that there will be risks of significant impacts on the environment that are not covered in this submission that we have not been able to sufficiently address in these submissions. We therefore may submit further information and evidence to the decision-maker prior to decision being made about this EMP.

Approval criteria not met

Under the *Petroleum (Environment) Regulations 2016* (*PE Regulations*) The Minister must approve an EMP "if reasonably satisfied that the plan meets the approval criteria, *before* approving the plan" (our emphasis added). Without significant amendment, this EMP fails this test in several respects. We iterate these failures throughout this submission but in summary:

- The EMP is incomplete with regard to *all direct and indirect risks*. Incomplete information about direct and indirect risks includes:
    - the proponent's undisclosed beneficial use intentions and impacts of the flare avoidance program;
    - undisclosed greenhouse emissions from supply of sand and transport of wastes interstate; and
    - the undisclosed impacts of sand mining to create local source of proppant (the company "has applied for 14 extractive mineral exploration licences in close proximity to the proposed Shenandoah South Pilot Project for the evaluation of and future extraction of frac sand."[1])
    - Indirect risks associated with groundwater extraction, and direct and indirect risks associated with wastewater management.
- The EMP is incomplete with regard to "*the cumulative effects of those impacts and risks* when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity."[2] The proponent makes no attempt to describe the cumulative climate impacts of exploration and production activities on the environment in which this fracking is proposed to take place, nor is there cumulative impact assessment of impacts on biodiversity and groundwater, beyond mere addition of tonnes of greenhouse emissions, hectares to be cleared and volumes of water to be extracted, none of which describe the "effects" of these impacts.
- Despite being incomplete, there is sufficient information to indicate that impacts will not be managed to be "as low as reasonably practicable" (ALARP). The ALARP requirement is not met with regard to, inter alia, the proponent's complex wastewater management system and drill cutting waste disposal and the greenhouse gas emissions from the project.

[1] Tamboran Resources. 15 December 2023. "ASX announcement: Tamboran enters Strategic Partnership with Liberty Energy to deliver modern stimulation and completion equipment to the Beetaloo Basin." https://www.listcorp.com/asx/tbn/tamboran-resources-limited/news/tamboran-enters-strategic-partnership-with-liberty-energy-2972507.html

[2] *Petroleum (Environment) Regulations 2016*, regulation 3(2)(b).

- Despite being incomplete, there is sufficient information to conclude that impacts not reduced to acceptable level with regard to water resources, particularly the risk of pollution, given the proponent's track record and the sensitive downstream environment.
- Among the approval criteria of the PE Regulation is that the EMP must, under s 9(1)(b) "be appropriate for the nature and scale of the regulated activity to which the plan relates." This is not the case for this EMP. There are numerous areas in which the EMP fails to meet this criteria. The scale and nature of this activity are such that it is inadequate to rely solely on the Code of Practice for management of impacts, and on the limited baselines established by the SREBA for the articulation of impacts. The nature and scale of the activity requires, for example, dedicated on-ground surveys for wildlife, more extensive groundwater monitoring, aquifer knowledge and greenhouse gas assessment.

Ecologically Sustainable Development

The principles of ESD are relevant in the approval of an EMP. ESD principles are established in Territory law under the *EP Act*, including, inter alia:

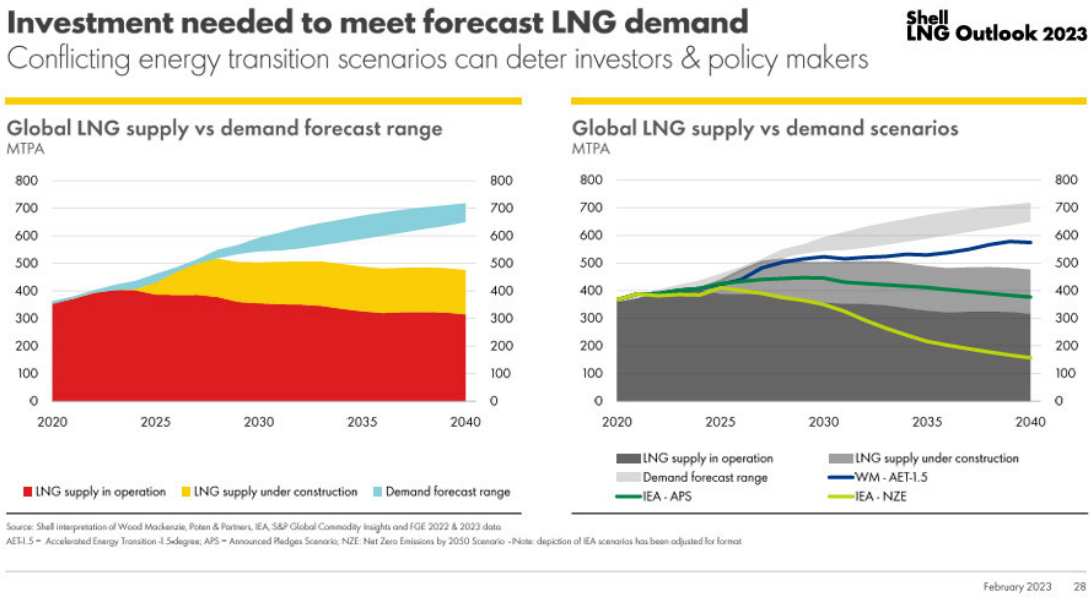
- Decision-making processes should effectively integrate both long-term and short-term environmental and equitable considerations;
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of present and future generations;
- Natural resources should be used in a manner that is sustainable, prudent, rational, wise and appropriate.

Tamboran concedes in its EMP that "exploration activities are an essential step in defining a potential future commercial resource" (section 2.1). While willing to claim the purportedly "sustainable, long-term benefits to the local community, to the Barkly region generally and more broadly into the rest of the NT," (page 35) of the full-scale production for which this project is "essential," the EMP does not engage with the profound inter-generational inequity of exploiting this resource, and its climate change implications. In this regard, the EMP fails to achieve the approval criteria for information completeness, cumulative impact assessment and impact acceptability.

Specifically, Schedule 1 of the PE Regulations, regulation (3)(2)(a)(i) requires assessment of "all the environmental impacts and environmental risks arising directly or indirectly" from "all aspects of the activity" and regulation (3)(2)(b) requires assessment of "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred **or may occur** in or near the permit area for the regulated activity" (our emphasis). Clearly, the proponent anticipates exploitation of "future commercial resource" and encompasses claims about the benefits of this exploitation within the scope of its EMP. To address **all the environmental risks and impacts arising indirectly** from **all aspects of the activity** and the cumulative effects of those impacts and risks that may occur, requires the proponent to describe the

global warming scenario that is consistent with its plans for full scale gas production and the **effects** of that warming on the environment of the NT.

In June 2023, an investment presentation by Tamboran cited an "emerging LNG supply shortfall" as context for its business strategy, utilising a graphic drawn from Shell's *2023 LNG Outlook*, purportedly showing a "gap" in LNG supply globally against forecast demand. Below is the actual graphic from Shell's *Outlook*, which clearly indicates that LNG supply in operation is sufficient to manage demand under the International Energy Agency's Net Zero scenario.



Source: Shell LNG Outlook 2023. February 2023.

The graphic actually demonstrates that the gas demand upon which the justification for this project rests is consistent with global warming above 1.5 degrees. This degree of global warming is among **the environmental risks and impacts arising indirectly** from **all aspects of the activity** and the cumulative effects of those impacts.

Relevantly, in its consideration of the principles of ESD, the EMP cites the Fracking Inquiry Final Report Statement that "… **provided that all of the recommendations made in this Report are adopted and implemented in their entirety**, not only should the risks associated with an onshore shale gas industry be minimised to an acceptable level, in some instances, they can be avoided altogether" (quoted in EMP page 35) We note that the necessary precondition for this, "all of the recommendations made in [that] Report are adopted and implemented in their entirety" is not met and therefore, this test for acceptability of the risks associated with an onshore gas industry is not met.

Recommendations still outstanding include:

- **Recommendation 7.12: Requirement that enclosed tanks must be used to hold all wastewater.** We note that this EMP includes extensive use of evaporation ponds as a wastewater management tool.

- **Recommendation 7.17 discharge of any wastewater to be prohibited**. Despite the prohibition created in the *Water Act 1992*, we note that this EMP proposes that the operation will include the discharge of wastewater.
- **Recommendation 9.8: That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions** emitted in Australia from any onshore shale gas produced in the NT. The direct greenhouse gas emissions resulting from this project will increase NT's emissions by more than 3.4% and full lifecycle emissions in Australia have not been estimated.
- Recommendation 7.15: **gas companies must submit details of the locations of all faults that could compromise well integrity.** There is limited mention of faulting in the EMP and the risk that encountering faults poses to groundwater.

The EMP also claims the activities "do not constitute threats of serious or irreversible environmental damage and there is no impact on the conservation of biological diversity and ecological integrity" (page 35). We submit that the proponent can only have come to this conclusion on the basis of the willfully incomplete assessment that has been made, particularly with regard to the impacts of climate change which are already at the threshold of inflicting serious and irreversible environmental damage, impacting on biological diversity and ecological integrity. Relevantly, there is considerable evidence available that global average temperature rise is near to passing the threshold of 1.5 degrees above pre-industrial levels, and institutions such as the International Energy Agency (IEA) have concluded that to prevent this threshold being breached, there is no room for new gas production anywhere in the world.[3]

The EMP falsely claims that "*there is no impact on the conservation of biological diversity and ecological integrity as a result of the proposed activities*" (p. 35). In fact, the proposed activities would result in the clearing and fragmentation of intact vegetation with moderate to good habitat values and no weeds. This will expose an intact community to a suite of indirect impacts including weed infestation, predation by exotic pests and movement barriers. These particular impacts are implicated in the catastrophic declines and extinctions of small mammals and ground-dwelling birds in the NT (Woinarski et al. 2014).[4] This is even more significant in the context of a rapidly growing number of similar impacts occurring in the surrounding area which is data deficient and poorly conserved.

We note that under s 24(3) of the *EP Act*, the ESD principle of improved valuation is described as including, for the purposes of Territory law "Users of goods and services should pay prices **based on the full life cycle costs of providing the goods and services,** including costs relating to the use of natural resources and **the ultimate disposal of wastes**." Tamboran has made no attempt to describe or estimate the full life cycle costs of providing the gas it proposes to extract under this EMP, nor the cost of disposal into the atmosphere of waste escaping methane and other greenhouse gas emissions. We submit that the inclusion of "full life cycle costs" in the valuation principle engages

[3] IEA, 2021. *Net Zero Roadmap*. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach/executive-summary

[4] Woinarski J., Traill B. & Booth C. (2014). *The modern outback: Nature, people and the future of remote Australia*. Report prepared as part of the 'Outback Papers' & co-ordinated by The Pew Charitable Trusts.

the decision-maker on the question of downstream emissions from the use of the gas proposed to be extracted in activities under this EMP.

Impacts on water resources

This activity is occurring adjacent to a floodplain drainage system feeding into Newcastle Creek, and ultimately, to Lake Woods. The EMP is dismissive of the possibility that the wastewater management and chemical handling activities on the drilling and fracking sites could lead to contamination of this wetland of national significance, but in our view this risk is present, significant and not reduced to an acceptable level by the management actions proposed in the EMP. In big floods, surface water from the site would flow to Newcastle Creek as south of Daly Waters all surface water flows south. Lake Woods is primarily fed by Newcastle Creek from a large catchment to the north-east of the lake. The unacceptable risk to surface water arising from wastewater and chemical handling are addressed further below.

The EMP envisages 8.5km of piping above and below ground in an elaborate multi-site wastewater management scheme. It is not clear whether this system will only be used for certain types of wastewater or if a single system will be used for flowback water, produced water and drilling fluid waste. This is a high risk proposal not described in any real detail and cannot be approved. It is claimed in Appendix H that "All the proposed activities for the exploration program are planned during the dry season" but also that "Where activities occur outside, Tamboran's Wet Weather Contingency Plan will be implemented" (page 21) This contingency plan is not provided; instead, the proponent indicates it will create the plan and submit as a revision of the EMP in October (Appendix H page 29). In any case, storage and transport of wastewater and drill-cuttings is an activity associated with the EMP that is clearly anticipated to take place during the wet season. We note that the Code of Practice requires that "During the wet season, **the transport of chemicals and wastewater on unsealed roads must not be undertaken unless the risk of spills is demonstrated to be ALARP and acceptable. This assessment must be included in the EMP** and established through a specific assessment of spillage risks in the circumstances" (A.3.8).

Professor Currell's advice indicates that the EMP has underestimated the risk of spills and leaks of fracking wastewater. Currell cites "A review by Patterson et al. (2017) of tens of thousands of shale gas wells across four US states [which] indicated that spills of potentially contaminating fluids from unconventional gas (particularly flowback water) occur at rates of between 2 and 16% of active wells per year, with the majority occurring in the first three years of a well's life." Approximately half of these were associated with transport and storage of fluids through flow-lines. Given this, Currell describes the EMP's designation of the risk of spills as "remote" as "overly-optimistic" and finds that "Due to its chemical composition (see Table 20), any release of such fluids is highly likely to cause environmental harm in the nearby environment."

The *Water Act 1992* prohibits fracking wastewater releases to surface water bodies under section 17A. The EMP claims in its summary that "No wastewater release to surface water proposed" (Table

8) but elsewhere contemplates “Most of the water will be re-used, with any unused groundwater **released through a controlled discharge to the area surrounding the lease pad**” (page 83, our emphasis). Furthermore, unintended release of wastewater has already occurred at sites operated by this proponent and arrangements are not in place to confidently prevent this again. Given the operation is upstream of Lake Woods, the proponent’s history of spills and improper handling procedures is relevant to the decision being made about this EMP.

The Code of Practice at section C.4.2.2 lists mandatory requirements for produced water and flowback fluid, including that “All produced water and flowback fluid **must be held in above-ground enclosed tanks at all times** following release from the petroleum well” unless in specifically listed circumstances, including being treated for reuse or disposal. The EMP does not achieve this mandatory requirement, and expressly proposes the holding of large volumes of wastewater in open ponds and tanks for the purposes of evaporation. The EMP describes evaporation as a “treatment” process (page 92) but the process of evaporation is in fact the opposite of treatment - concentrating pollutants that are held in the environment, according to the proponent’s plans, in open storages, vulnerable to leaks, spills and floods. The evaporation process concentrates contaminants from drilling fluids and flowback and produced water, including potentially radionucleides, which may, once dried, become mobilised by wind. This risk is identified by expert Daniel Soeder in the attached advice, but is not anywhere addressed in the EMP. It is proposed that contaminated material will be left in place on site during the wet season and while the freeboard of sumps is proposed to allow for a 1:1000 AEP rain event, the EMP also anticipates that this contaminated wastewater will be “transferred to wastewater tanks for storage and evaporation.” The ability of these installations to withstand inundation is unclear and gives rise to an unacceptable risk of uncontrolled pollution during a flooding event. Professor Currell in Attachment B finds that the risk of overflow and leakage from these storages “cannot be fully eliminated by the proposed design and control measures.”

It is proposed that the activity will include, “Construction and operation of wastewater gathering lines to a centralised wastewater treatment infrastructure located a [sic] Shenandoah S B” but these are not shown on the simplified “Figure 32: Site water management schematic.” The water balance table indicates the largest wastewater storage requirements at Shenandoah South 2. The contradictory and unclear information presented about wastewater management require detailed further inquiry by the Department and clearly fail the approval criteria. The Code of Practice section C.6.1(b) requires that “Wastewater tracking must be documented in an auditable chain of custody system.” There is no mention of this requirement in the EMP and it is clearly necessary given the proponent’s track record and the complexity of the arrangements for managing wastewater across multiple sites.

Remote cameras or sensors are proposed to be used to monitor wastewater volumes during the wet season (page 118), and mention is made of crews remaining on site during the wet season, but insufficient detail is provided in the EMP about remedial action that will be available during the wet season to prevent spills of contaminated wastewater during the wet season should remote sensors detect a problem.

There are numerous places in the EMP where sentences are unfinished (for example “All water treatment systems will either be zero liquid discharge or produce a freshwater compliant with that will be irrigated into the surrounding area” page 113). We are profoundly concerned at the cavalier

approach to environmental risk mitigation and management that these basic gaps and confusions indicate.

With regard to groundwater, section B.4.17 of the Code requires an accurate understanding "of the relationships of aquifers to each other" as a mandatory requirement for all operators. The information provided in the EMP does not set this out. The depths of aquifers is indicated, and their geological age, but the hydrological connections between them (if any) are not described at all. This is information critical for understanding whether the introduction of large volumes of water with fracking operations in the deep formations could potentially influence the hydrology of overlying aquifers. Prof Matthew Currell in Attachment B highlights this gap, observing that site specific properties, such as permeability, of the formations is not provided and "it is unclear whether key units between the target shales and high-value aquifer(s) – e.g. Gum Ridge Formation - are likely to act as effective aquitards or aquifers, particularly the Bukalara Sandstone and Antrim Plateau Volcanics." The SREBA indicated that connections between the deep and upper aquifers are rare, but can occur where there is faulting, including to the surface. As Currell identifies, the level of connectivity across the sub-Basin is variable, "and without site-specific hydraulic testing to explore deep-shallow aquifer connectivity at the Shenandoah South site, it is not possible to say whether such connectivity is likely to be significant or not." The SREBA identified areas in the Beetaloo sub-basin where there is potential for "current and post-Cambrian fluid flow" and the scale of drilling proposed in this EMP requires a risk assessment that includes the potential for contamination if faults are encountered. Indeed, the EMP admits that a "casing deformation event" occurred during drilling at Amungee, implying that this occurred because a fault was encountered, but states without evidence that in that instance there was "no risk of interconnectivity with surface aquifers" (page 118).

It is asserted that there are effective geological barriers between the target formations and the Gum Ridge Formation, but also that, "The effectiveness of geological barriers to fracture height growth will be assessed prior to stimulation with geomechanical data from core analysis, wireline log data and modelling" (p 147). This assessment is required prior to fracking proceeding, in keeping with the precautionary principle and in order to meet the ALARP test. It is also asserted that:

> *The limestone in the CLA is commonly fractured and cavernous; in the Katherine region, bore yields of up to 100 L/s have been recorded from this aquifer (SREBA, 2023). Such high yielding sections were encountered when drilling the Kyalla 117 N2-1 E&A well through the Anthony Lagoon and Gum Ridge Formation, with total losses of drilling fluid circulation at specific intervals. (page 155)*

It is not totally clear what the proponent means here, but it appears that there may have been "total loss" of drilling fluid, including its chemicals, into the productive aquifer that is relied upon by water users in the region. If this is the case, this is a further risk that remains undescribed in the EMP for the current proposal.

If there is no hydrological connection between the formations, then this is necessary information to include. If there is, then the movement of water between aquifers, and the introduction of fracking fluid to that movement, must be described and assessed.

Furthermore, section B.4.17.1 of the code mandatorily requires "**At least six months of local baseline data for water quality indicators of the key aquifers that may be affected by the activity must be acquired prior to drilling**." Indicative timelines in the schedule supplied at Figure 5 of the EMP does not indicate that there will be six months of data from new groundwater monitoring bores at Shenandoah North A, Shenandoah South 2 or Shenandoah South B. Each of these indicates a 1-3 month interval only between creation of groundwater monitoring and extraction bores and the drilling of the first wells.

It is estimated that up to 375 ML/year of water will be extracted from the Gum Ridge Formation across the Shenandoah South to support the proposed activities under this EMP. The proponent's current licence (WEL GRF 10285) provides for less than half of this volume. The EMP indicates that "The WEL will be increased to cover the future proposed exploration activities" and that this application "is covered under the Water Act and is separate to this EMP" but the impacts of doubling extraction are relevant to the considerations of this EMP. While the total sustainable yield of the Gum Ridge Formation has been determined to be much larger than this, the short-term impact of removal of large volumes of water in a concentrated area requires assessment in this EMP. As Professor Currell notes in his advice, this degree of extraction may affect the yields of several pastoral bores within 7km of the proposed extraction bores. Currell also notes that this groundwater extraction "will also reduce the flux of water (in the long term) leaving the region as groundwater throughflow and/or discharge, changing the aquifer water balance" with potential effects, including cumulative impacts, on groundwater dependent ecosystems and that these impacts are not assessed at all by the EMP.

Review of the "Typical process water balance for each site" at Figure 33 indicates large volumes of water not being recovered from fracking activities. In Shenandoah South 2, in December 2025 for example, 200.8ML is expected to be used in well stimulation, but only 16.2ML wastewater generated by drilling activities and no "recycled flowback wastewater." Smaller quantities of waste water are listed in the subsequent six months, and "waste water stored on site" increases incrementally from 18.53 in December 2025 to 33.84ML in May 2026 (page 115). These figures are roughly equivalent to the assertion elsewhere in the EMP that the proponent anticipates 15% recovery of fracking fluid (30ML from 200ML) and roughly correlate with the claim that the operation will have "Peak flowback storage volume of approximately 34 ML." However, given the complexity of the proponent's wastewater management arrangements, moving water from site to site via pipes and from open to closed containment with different needs for flowback water, drilling waste and production water, contingency plans are necessary for the possibility that there will be greater volumes returned to the surface. This is particularly the case in that the six month recovery period for water indicated in this table is far longer than the 60 days cited elsewhere in the EMP as the period in which most flowback water is recovered. It is also unclear what analysis was used to derive the figures in the Table or how confident the proponent is in them. If this is actually a representation of the complex wastewater transfer and management scheme proposed in the EMP, it requires interrogation. As another example, in November 2025 there is 15.2ML of water at Shenandoah South 2 listed as being transferred to the Kyalla site, but no corresponding line item in the water balance for that site. The same occurs for a transfer of 32ML in April 2027 and there other instances of this in the table. These occur in months when large water usage is listed at the receiving sites for fracking stimulation.

Professor Currell also notes that in the EMP's chemical risk assessment there are a number of "proprietary" compounds (using the prefixes DCA- and BE-) listed among the chemicals to be used whose names do not describe the specific molecule/compound, meaning an assessment of the risks associated with use, handling and exposure to these compounds may not have occurred. Prof Currell identifies eleven compounds with the DCA- code where it is unclear whether the chemical has been assessed. Multiple other chemicals listed in Table 6 of the EMP do not appear in the Tier 1 or Tier 2 assessments in Appendix E. Prof Currell identified one of the compounds with a letter code "BE-9 biocide" to be Tributyl tetradecyl phosphonium chloride – a compound with very high acute toxicity, and for which biodegradation information is currently not available. It is far from clear if the high risk presented by the use of this chemical has been assessed or understood. Furthemore, Professor Currell reports that it is unclear whether "breakdown products" of the chemicals proposed to be used in the fracking mixtures have been identified and analysed for potential toxicity in the risk assessment.

Sand mining

The full life cycle costs of the proposal include costs relating to the use of natural resources and disposal of wastes, particularly when these are essential to the fracking process. In this respect the EMP is also incomplete in that it does not describe the impacts of sand mining the proponent has announced it intends to undertake to support its fracking activities in the Beetaloo sub-Basin.

By our estimate, based on per well estimates in the EMP, for this project to drill and frack 15 wells will require 56,250 tonnes of sand in total. We note that on 14 December, Tamboran announced to the ASX that it had, via its subsidiary Tamboran Infrastructure, applied for "14 extractive mineral exploration licences close to the proposed Shenandoah South Pilot Project for the evaluation of and future extraction of frac sand." The location of these are not disclosed but the implication is that this sand extraction project will support the current application for fracking at Shenandoah. We note that reference to proppant in this EMP suggests that it will be sourced "from locations within Australia (such as South Australia) or imported from international sources."[5] It is therefore misleading, given Tamboran's recent applications for 14 extractive mineral exploration licences. Therefore, the impact of this proposed sand mining is an indirect impact of this activity and needs to be described and assessed as part of this EMP.

Drill waste disposal

The monitoring program for heavy metals and other contaminants summarised in Table 30 of the EMP refers to Table 10 of the Code for the analytes to be included in analysis of drilling fluid and cuttings, but this reference should be to Table 9.

The risk from handling and disposal of solid drilling waste and drilling fluid has not been reduced to as low as reasonably practicable by the proponent. The Wastewater Management Plan at Appendix G does not achieve the mandatory requirements for management of drilling fluid under the Code under section C.4.1.2 and does not reduce environmental risks to an ALARP or an acceptable level. For example, Appendix G anticipates drying, blending and disposing of drill cuttings and muds on

[5] EMP, page 85.

site, without having undertaken the leachability tests required by the Code. Indeed, Appendix G indicates that "Dry, blended drilling cuttings/ muds may only be stored onsite **without secondary containment** where there is no risk of fluid leaching" (page 5, our emphasis). Section C.4.1.2 (f) of the Code clearly requires that "If seeking approval to dispose of residue from drilling fluids on-site, **the EMP that is submitted must include a certification from a suitably qualified third party that the material is of acceptable quality for disposal to land by the proposed method** and that environmental harm will not result from the proposed disposal." There is no evidence of such certification in the EMP.

The Wastewater Management Plan indicates that "Detailed assessments of the site-specific risk associated with the disposal of drilling fluids and muds as per condition C.4.1.2 of the Code, will be undertaken upon completion of drilling activities" (page 4). But this information is required to be included with the EMP for the adequate consideration of whether environmental risks have been reduced to as low as reasonably practicable.

The EMP further states that:

> *"If the material is unsuitable for on-site disposal (such as the moisture content is too high or the material is incompatible with surrounding soils or the analysis of the material indicates it is inappropriate for on-site disposal (as per C.4.1.2 of the Code),* ***the material may be left in-situ across the wet season*** *to allow for the material to dry during the subsequent dry season or be transported off-site. If on-site disposal is not feasible, all solid material will be transported off-site to an alternative suitable exploration location or a licenced facility. Off-site disposal will be undertaken in accordance with the NT Waste Management and Pollution Control Act 1998" (Page 109, our emphasis)*

If material is deemed to be inappropriate for on site disposal, then leaving it in place during the wet season presents an unacceptable risk. It is far from clear in the EMP that all containment areas on the site will be constructed to withstand the probable maximum flood level and the proponent has failed to satisfy basic need to understand, prevent and manage risk from concentrated contaminants in drill-cuttings.

There are frequent references in the wastewater management discussion to evaporation as the "primary" strategy for managing volumes of wastewater. Evaporation will lead to concentration of contaminants in brine or dry material. Twelve months after well testing commences "approximately 20 B-Triples will transport the residual flow back to an approved disposal location" (EMP, page 113). The location for disposal of "residual solids, brines, sludges and liners" is a facility in Jackson, Queensland, but authorisation will be required for interstate waste transfer and no alternative location within the NT is specified. Professor Currell's advice indicates that in the absence of clear details and discussion of the end-point disposal point for contaminated materials "it should be considered that the proposal will potentially produce a legacy of hazardous wastes that may pose an ongoing risk to the environment."

Environmental performance of proponent

Section 6(1)(d) of Schedule 1 of the *PERegulation* requires that the Implementation Strategy of an EMP includes "monitoring, recording, audit and management of non-conformance with the plan and review of the interest holder's environmental performance." The EMP does not provide a review of the environmental performance of Tamboran, but this record is relevant to its claims that risks are acceptable.

The chemical pathways exposure analysis describes the effectiveness of controls to prevent on- and off-lease release via spills as "High" claiming, "the use of secondary containment, bunding and gathering systems controls reduces the probability of an off-lease release via a spill down to 'remote'" (page 106), but the recent history of the proponent reveals such incidents have already occurred. The exposure pathways analysis in Table 18 similarly asserts confidence in the "high" effectiveness of prevention methods for release of particulates from chemical spills. The exposure pathway analysis amounts to an assertion of the effectiveness of the regulations and standards, not the effectiveness of Tamboran's operations and risk management procedures.

A complete list of recordable and reportable incidents occurring on Tamboran sites in the last eighteen months is appended to this submission. These incidents include:

- Holes discovered in the liner of a tank being used to store waste solids, resulting in a spill to the hardstand;
- A spill of 3,520 litres of drilling mud to the ground because of poor condition of hoses;
- A spill of 800L of flowback water as a result of another leaking linter in a wastewater tank;
- A spill of 1000L of sodium bromide while site bunding was out of service;
- Alleged pumping of contaminated water from the "Maverick 1" well site onto Tanumbirini Station;
- Failure of bunding at the Maverick 1 site during a heavy rainfall event;
- An estimated 314,600L of low EC drilling wastewater estimated to have been mistakenly utilised for dust suppression in order to lower fluid levels in a tank above the wet season freeboard level.

Tamboran's incident rate is higher than the 1 in 200 well rate cited by expert Daniel Soeder in his attached advice, arising from a two-state comparison of environmental incidents associated with gas wells in Ohio and Texas.[6] Soeder also notes that for the major incidents among these, surface spills were most commonly the cause and "more to do with the competence of the operator rather than the type of well" (Page 38 of attachment). Prof Currell's advice cites a 2014 study which found "integrity failures occur in approximately 2 to 75% of oil and gas wells over their lifetime. Taking the Marcellus Shale (a major unconventional shale gas resource in the US) as an example, 6.3% of wells reported well barrier or integrity failures in the period examined." Currell reports that applying this rate to the current project suggests that at least one of the 15 proposed wells will be likely to experience an integrity issue over its lifetime.

The same is true of the risk of subsurface release of chemicals to aquifers. The EMP in Table 18 describes the regulatory guidance as mature and the industry as experienced, but these assertions

[6] Soeder cites Kell, S., 2011, State oil and gas agency groundwater investigations and their role in advancing regulatory reforms: a two-state review, Ohio and Texas: report prepared for the Groundwater Protection Research and Education Foundation of the Ground Water Protection Council, p165.

do not go to the particulars of this operation and this operator. They could generically be said in any EMP and it cannot be the case that the requirements of an EMP can be generically met with standard reiteration of regulatory arrangements and industry confidence. What is required in an EMP is a description of the *particular* risks of the activities proposed, arising from constraints and sensitivities of the location, the capacity, competence and capability of the proponent and the particular manner in which the activities will be carried out. This is a requirement set out in Schedule 1 of the *PE Regulations*.

Given this history of incidents relating to handling, oversight and spill prevention, it is clear that the environmental risks of this operation are not reduced to as low as reasonably practicable. Acknowledgement of this, and descriptions of additional measures beyond those mandated by the regulations which are already in place, is necessary for this EMP to meet the approval criteria.

Biodiversity

The activities described in the EMP are likely to have a significant impact on biodiversity and Commonwealth-listed Matters of National Environment Significance (MNES) and should be referred to the NT EPA for assessment under the *EP Act 2019* and to the Commonwealth as a controlled action under the *EPBC Act*. The EMP provides only a superficial overview of the ecological values of the lease area, relies on unreliable records and does not offer any effective mitigation measures. Furthermore, the EMP:

- Does not demonstrate alignment with the principles of Environmentally Sustainable Development, specifically the conservation of biological diversity and ecological integrity;
- Is based on inadequate survey effort;
- Is reliant on SREBA surveys which, far from being comprehensive, represent only an initial and incomplete snapshot of biodiversity in the Beetaloo Basin;
- Is overly reliant on database records, rather than dedicated surveys, for flora, fauna and ecological communities to determine likelihood of occurrence;
- Fails to assess cumulative impacts in the context of current and future gas development;
- Fails to adequately assess or mitigate the direct and indirect impacts of habitat fragmentation;
- Fails to adequately consider indirect impacts on Lake Woods, a site of high ecological and cultural significance.

These are discussed further below.

Inadequate survey effort

Biodiversity assessment conducted as part of the EMP consisted of a desktop survey and an aerial rapid condition assessment with some targeted ground-truthing. The authors claim to have "a good understanding of the natural environment" for the Shenandoah lease area based on the many reports produced between 2004-2023 (Appendix K: Land Condition Assessment Report, page 4). However, the reports are very limited in their scope and coverage of specific drill sites. They predominantly catalogue the cumulative removal of vegetation but do not monitor the impacts of past clearing. There has been no attempt in the EMP to address the considerable gaps in the SREBA

surveys. The surveys undertaken are inadequate and seek only to quantify the vegetation to be lost with no attempt made to confirm threatened flora or fauna records.

The EMP claims that no significant or sensitive vegetation, narrowly defined as wetland, floodplains/drainage depressions and run-on areas, would be directly impacted by the proposed activities. No significant flora species were recorded as comprehensive floristic assessments were not undertaken. Similarly, no fauna sightings were recorded during April 2023. Table 24 in Appendix K lists incidental observations of nine common bird species and one reptile species recorded in December 2022. This is a superficial analysis of biodiversity.

Although threatened Gouldian Finch and Crested Shrike-tit were targeted through searches and call-playbacks, the survey effort (i.e. number of hours, days, sample sites) is not described in the EMP, including limitations of survey timing and methods. It is clear that the EMP depends on the deficient SREBA surveys to identify and target threatened species.

This level of survey effort is unacceptable and will lead to the cumulative loss of biodiversity in the short-, medium- and long-term. The SREBA surveys were regional in scale, not comprehensive and left significant outstanding data gaps in biodiversity at the targeted sites.

Inadequate SREBA surveys

Recommendation 15.1 of the Pepper Inquiry stated that the lack of "*adequate pre-development assessment and environmental baseline data is routinely cited as one of the biggest issues associated with the rapid development of the shale gas industry*" (recommendation 15.1). Unfortunately, despite the SREBA surveys, this issue remains unresolved and we remain in the inadequate data situation identified by the Inquiry with regards to biodiversity.

Justice Pepper estimated that, for the Beetaloo Basin, the assessment of terrestrial and aquatic biodiversity would take in the order of three to five years to undertake. However, SREBA surveys were undertaken between June 2020 and May 2022 and included only two wet seasons. They were plagued with limitations including:

- Covid restricted access to some survey sites to a single visit, making seasonal comparisons impossible;
- Fauna surveys were restricted to a single four-night stay and six weeks of camera trapping (five cameras deployed) at each site;
- The survey period included poor wet seasons with no opportunities to extend timeframes to include the good wet season of 2022/23;
- Migratory bird surveys were not undertaken;
- Only a limited range of fauna groups was surveyed;
- Aquatic field work was restricted to single visits during two dry seasons.

The SREBA guidelines noted that established sampling methods should be applied that:

- provide sufficiently high detection probability for robust analysis of geographic patterns and detection of change in community composition over time, and

- must not have access or resource constraints (cost, personnel or time) that prevent them from being effectively applied over a large number of sites within the scope of a SREBA.

However, this was not the case for the SREBA, where access constraints associated with Covid restrictions did not result in extended timelines, but instead, ended surveys prematurely thereby missing important seasonal variation and preventing survey replication. Moreover, the Shenandoah EMP demonstrates that the rapid survey methods are unable to confirm the presence/absence of threatened species, let alone to detect and monitor the more subtle patterns within and changes to communities.

The biodiversity studies in the SREBA represent a preliminary and incomplete assessment of the conservation values of the Beetaloo Basin. The paucity of ecological data collected in the NT prior to 2018 has been noted in the Pepper Inquiry report and in the SREBA and the surveys undertaken to date only scratch the surface and needs significant additional work in order to make confident assessment of the impact of gas development in the Beetaloo Basin in general and this application in particular. There is therefore still considerable uncertainty around the species/communities present, their distributions, their conservation status and their reservation status.

The high number of new species records and apparent range extensions found in the SREBA indicate the lack of previous survey work and systematic monitoring. Species accumulation curves presented in Section 6.4.3 of the SREBA indicate that a greater number of survey sites needs to be sampled in order to capture the full suite of species present. The SREBA surveys recorded 6,471 new plant records and 1,093 new plant taxa in the Beetaloo Basin, representing a 43% and 18% increase on pre-survey conditions, respectively. Three restricted range plant species were recorded in the study area for the first time. In addition, surveys detected only two threatened species, 22 Near Threatened and 83 Data Deficient species. The latter figure emphasises that information regarding the conservation status of plants is inadequate.

SREBA surveys targeted a limited range of fauna groups including birds, non-flying mammals, bats, reptiles and ants. There were 14 new vertebrate species recorded in the study area. Range extensions were observed for two species. In addition, there were 11 threatened species, 18 Near Threatened and three Data Deficient fauna species recorded in the study area. As noted for flora species, it is clear that fauna records in the NT are deficient and additional survey work is required to get a more accurate indication of fauna distribution and abundance.

Of the four targeted threatened species considered in the SREBA, Crested Shrike-tit was recorded at 37 new sites, Gouldian Finch was detected at 52 new sites, Greater Bilby at 15 new sites and the Yellow Spotted Monitor at 22 new sites. Further surveys are likely to uncover more site records and further increase our understanding of these species' distributions. EMPs cannot rely on SREBA survey data alone and must undertake detailed surveys on a case-by-case basis that target a wide range of potential threatened species and not just those highlighted in the SREBA.

Likelihood of threatened species

The EMP has not demonstrated that nationally threatened species will not be significantly impacted. It has not even confirmed the presence or absence of targeted species.

Although the EMP states that a "conservative" approach has been taken to assessing likelihood of threatened species occurring in the lease area, it has in fact relied on recent records which are an indication of the lack of survey effort rather than to species' absence. Amongst the species for which suitable habitat was available, the likelihood of occurrence was further restricted if breeding habitat was not present, or it did not qualify as "core" or "critical" habitat, even though these terms are not defined. By this reasoning, only the most critical breeding habitat for threatened species will be avoided at the expense of foraging and refuge habitats and movement corridors that are critical to maintaining resilience in the face of climate change.

Consequently, the probability of eight threatened species' occurrence at Shenandoah is considered only as "possible" by the EMP even though suitable habitat is present (Gouldian Finch, Painted Honeyeater, Pale Field-rat, Common Brushtail Possum, Plains Death Adder, Yellow-spotted Monitor). Presence of the Crested Shrike-tit is only considered "possible" even though it is known to use Eucalyptus/Corymbia habitats; it was not considered to be an "important" area for this species. The only species considered "likely" to occur are the relatively common migratory species - Cattle Egret, Fork-tailed Swift and Rainbow Bee-eater – coincidentally amongst the least likely to be affected by habitat clearing and fragmentation.

The Spectacled Hare-wallaby is closely associated with the Lancewood-Bullwaddy vegetation community that covers the impacted area. This species is listed as Near Threatened and is declining in the NT and is a Critical Weight Range (CWR) mammal most vulnerable to predation by introduced predators. It is also rare in the Kimberley and Pilbara regions Western Australia and was recommended for listing as Vulnerable in the NT by Ingleby in 1991.[7] If the EMP had taken a conservative approach to its assessment, it would have considered this species in detail as it is likely to be significantly impacted by gas development in the Beetaloo.

The EMP concluded that impacts to stygofauna were "highly unlikely" due to the depth of the groundwater, likely low abundance of stygofauna and limited drawdown at Kyalla extraction bores, and predicted that any impacts were likely to be "extremely localised." It refers to previous reports prepared by CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) (2020)[8] and the extensive surveys conducted as part of the SREBA, to support its findings. However, the SREBA Stage 2 groundwater studies came under scrutiny when the contract for Charles Darwin University that undertook Stage 1 of the study, was abruptly cancelled due to comments made in the media. about 11 new species of stygofauna discovered by CDU researchers during Stage 1.[9]

Cumulative impacts

[7] Ingleby S (1991). Distribution and status of the spectacled hare-wallaby Lagorchestes conspicillatus. *Wildl. Res.* 18(5): 501-519.
https://www.publish.csiro.au/wr/WR9910501

[8] GISERA (2020). *Characterisation of the stygofauna and microbial assemblages of the Beetaloo Sub-basin, Northern Territory*. https://gisera.csiro.au/wp-content/uploads/2021/03/GISERA-Project18-Stygofauna_final-report-20201208.pdf

[9] *The Conversation* 16 February, 2021. "Blind shrimps, translucent snails: the 11 mysterious new species we found in potential fracking sites."
https://theconversation.com/blind-shrimps-translucent-snails-the-11-mysterious-new-species-we-found-in-potential-fracking-sites-155137

The total area that would be cleared/disturbed as a result of Shenandoah South E&A activities is 145.26 ha, including 119.01 ha of new clearing and 26.25 approved clearing. Combined land clearing from the current EMP, EP 117 and 98 and all disturbance associated with Tamboran B2 activities, is approximately 325 ha and the current estimated cumulative clearing over all current operational EP areas is about 888 ha. This is a substantial amount of clearing that has been approved without adequate assessment given the paucity of ecological data available.

As with all the EMPs prepared to date, the Shenandoah EMP seeks to minimise the amount of clearing by presenting it in a regional context. The 325 ha for example, represents only 0.018% of the total surface area of the combined lease area of 18,555 km^2. By the same faulty reasoning, the combined cumulative clearing of all of Tamboran's leases and neighbouring EPs amounts to less than 0.02% of the total surface area of all current operational EPs. These percentages are meaningless in an ecological sense and highly misleading. They assume that all habitats are equally suitable for all species and ignore the fact that these areas will be subject to clearing for future gas development and pastoral activities given the very poor reservation status in the NT.

The Lancewood/Bullwaddy vegetation community that covers the Shenandoah South lease area and would be cleared as part of the proposed activities is brushed off as being of no significance as it is relatively species poor for flora and fauna (Woinarski and Fisher 1995)[10] and is regionally extensive. It is primarily restricted to the Sturt Plateau. However, Acacia woodlands are severely under-represented in conservation reserves with less than 1% conserved in the NT and 3% nationally (Parks & Wildlife Commission of the Northern Territory 2005).[11] The Bullwaddy Conservation Reserve located 81-87 km northeast of the Shenandoah South E & A Program, is the only declared conservation area containing this vegetation type within the Sturt Plateau. This community was identified in the Parks & Wildlife Commission Masterplan (1996) as being of high priority due to its poor representation in the parks estate.

An adequate cumulative impact assessment needs to take into consideration the conservation status of vegetation communities, which is extremely poor in the NT. Less than 1% of the Sturt Bioregion is protected in reserves (Woinarski et al. 2014). Many of the broad vegetation groups within the Sturt Plateau are poorly represented in conservation reserves including eucalypt forest and woodlands with tussock understorey (0.09%), eucalypt low woodland with tussock grass understorey (0.02%), and Acacia woodland including Mulga (0.48%). Of even more concern are the groups that are not reserved at all, including eucalypt woodland with hummock grass understorey, mixed species low open woodland, hummock grassland, tussock grassland and chenopod shrublands.[12] The Bullwaddy Conservation Reserve Plan of Management also notes that three species of ground-foraging birds have shown a clear association with lancewood and bullwaddy thickets in this region and that the

[10] Woinarski JCZ and Fisher A (1995). *Wildlife of Lancewood (Acacia shirleyi) Thickets and Woodlands in Northern Australia 1*. Variation in Vertebrate Species Composition Across the Environmental Range Occupied by Lancewooe Vegetation in the Northern Territory.

[11] Parks and Wildlife Commission of the Northern Territory (2005). *Bullwaddy Conservation Reserve Plan of Management*.

[12] Baker B., Price O., Woinarski J., Gold S., Connors G., Fisher A. & C. Hempel (2005). *Northern Territory Bioregions – assessment of key biodiversity values and threats.* Report prepared to accompany the Northern Territory Parks & Conservation Masterplan.

Spectacled Hare-wallaby is “unusually abundant” in bullwaddy thickets. Ground-dwelling birds and small mammals are most susceptible to the impacts of fragmentation and consequent edge effects.

The SREBA surveys marked the first time that ants have been surveyed in Lancewood/Bullwaddy habitats. Ant communities in open lancewood woodlands differed markedly from those in closed bullwaddy thickets. Fifteen (41%) of the 37 assessable species from the Bullwaddy site were not recorded elsewhere in the survey. This indicates that this community has unique characteristics that may not be visible to the naked eye.

Fragmentation impacts not assessed

Land condition for the Shenandoah South E&A Program was assessed as being moderate to good. Vegetation associated with seismic lines and access tracks are considered to be in good condition with no current evidence of weeds or erosion but some disturbance from cattle. Although no weeds were detected during the March-April 2023 surveys, three species were recorded in 2022. The four pad sites and seismic lines provide habitat for a range of species with high native grass cover for granivorous birds, dense leaf litter with scattered to numerous hollow-bearing trees and fallen logs. Although this intact weed-free habitat is most at risk from fragmentation and edge effects, this was not considered or even mentioned in the EMP. The only mitigation measure recommended was to avoid hollow-bearing trees where possible.

Appendix K (p. 40) cautions that land condition is threatened by impacts from weeds, feral animals, pastoralism and changed fire regimes. However, it does not admit that the current condition of the area is good despite these threats and that the proposed activities are the main factors that would drive weed infestation and feral animal increases. We can expect altered fire regimes to be a consequence of climate change, changing fuel loads and increased human activity. It is this combination of effects that is implicated in the extinction of fauna species in the NT and is highly likely to result in the degradation of existing habitat and isolation of populations in habitat islands. The species most at risk from fragmentation are sedentary ground-dwelling birds and small mammals, both of which are common in the Lancewood/Bullwaddy community.

The Pepper Inquiry cautioned that there is a high risk of substantial spread of invasive weed species associated with gas development in the NT due to the large number of personnel and vehicle and machinery movements. It was also noted that the Sturt Plateau was relatively free of weeds. It was recommended that weed management plans be prepared and that dedicated weed officers be assigned to each gas development to mitigate the risk of weed infestation. This has been done as part of the Shenandoah EMP. While Threat Abatement Plans have been prepared for five invasive grass species that are a Key Threatening Process under the *EPBC Act* and protocols for the control of declared weeds are specified in various codes and NT legislation, the control of other weeds that are equally invasive but not declared, is less clear. Any infiltration of weeds into this relatively weed-free environment would degrade native vegetation and threaten biodiversity values.

The EMP states that there is “*potential for pest species to be attracted to increased site activities causing an increased abundance in the landscape*” (page 192) and note that this is a threat

particularly for reptiles and ground-dwelling birds. This ignores the fact that 16 species of small mammals have gone extinct in the NT with one of the major causes thought to be predation by introduced predators. The EMP offers no mitigation measures to control this major threat to NT ground-dwelling fauna except to note that "*pest species control should be considered when undertaking site activities*." This is a major oversight and demonstrates a lack of understanding of NT threatening processes.

Potential indirect impacts on Lake Woods

The EMP has not considered indirect impacts of the proposed activities on the hydrology of Lake Woods, located approximately 90 kms to the south of the lease area but within the lake's catchment area. Of particular concern are the potential impacts of fracking on an ephemeral stream located 12km from the Kyalla well pad that feeds into the main drainage line to Lake Woods. This stream was not mentioned in the EMP although a stream located 13km from Shenandoah S2, SB and C was identified as a sensitive receiver. Reasons for excluding hydrological impacts relating to Lake Woods and Newcastle Creek are summarised as three dot-points on page 195 of the EMP. No mitigation measures are described.

Lake Woods is a site of outstanding ecological and cultural significance. It is one of the most important wetlands in inland NT and is recognised as an Important Bird Area (IBA) due to the large numbers and diverse species that visit it.[13] It is recognised as a Site of Conservation Significance by the NT Government. It is recognised as an important waterbird breeding area in inland NT and has historical records (1993) for critically endangered Curlew Sandpiper (*Calidris ferruginea*) and provides habitat for threatened species such Freckled Duck, Black-tailed Godwit and Pale-vented Bush-hen. Fifteen species of migratory shorebirds have been recorded at Lake Woods mostly between September and April.

The risk for Lake Woods is that bird surveys are only undertaken sporadically and no monitoring occurs and therefore any changes to the hydrology and consequent impacts to waterbird populations would go undetected. No waterbird surveys were undertaken as part of the SREBA. Waterbird records were instead collated via a desktop study and literature search; it revealed that a large number of records had not been entered into the NT Fauna Atlas, again confirming the poor state of NT data collection and record-keeping.

It is also noteworthy that major surveys undertaken since 1993 have increased the species list for Lake Woods. An aerial survey was conducted at Lake Woods only five years ago on 25 of May 2017, and contributed an additional 88 new records of waterbirds at Lake Woods (NT Government 2022). Similar to the other flora and fauna groups sampled as part of the SREBA, this indicates that the full range of waterbirds visiting Lake Woods is unknown and it is essential that more frequent survey and regular monitoring be implemented to detect changes in numbers and/or species due to hydrological changes.

Greenhouse gas emissions and air quality

[13] NT Government (2022). Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin.

The description of the greenhouse gas emissions, and associated climate harms, resulting from Tamboran's proposed Shenandoah South E&A program as set out in this EMP is by turns incomplete, misleading and opaque, and cannot form a proper basis for any decision that the EMP meets the criteria for approval under the *PE Regulations 2016*. We note too that the EMP makes no mention of the Ambient Air Quality National Environment Protection Measure (NEPM) and the release of air toxics from the activities proposed. Air toxics may be released on site as volatile organic compounds, as gases released from combustion and as windborne particulates of dried material after evaporation. The attached advice from Daniel Soeder provides some detail on this latter risk, which is increased by the proponent's proposed use of open ponds for storing contaminated water.

The Minister may only approve the EMP if reasonably satisfied that the EMP meets the approval criteria under the *PE Regulations* (s 11). The approval criteria include that the EMP includes "all the information required by Schedule 1 [of the *PE Regulations*]" (s 9(1)(a)).

The EMP does not include all the information required by Schedule 1 of the *PE Regulations* in relation to the proposed program's greenhouse gas emissions and climate change impacts.

Specifically, the EMP does not "include details of all environmental impacts and environmental risks of the regulated activity" as required by Sch 1, s 3(1)(a), because:

- The actual emissions impact of the exploration and appraisal program under currently known conditions has not been described. Instead, a proposed and undescribed "flare avoidance program" has been used to substantially – and misleadingly – lower projected emissions for FY2026 and FY2027, despite that program still being deeply uncertain and subject to Native Title consent, regulatory approval and the proponent's own unmade decision to expend "$10's of millions" on appraisal sale infrastructure.
- Obvious and significant sources of greenhouse gas emissions resulting from the project have not been included in the EMP's emissions quantification, including:
    - Direct emissions arising from developing and implementing the "flare avoidance program," including construction of infrastructure for sale of appraisal gas, and the processing, transport and combustion of sold appraisal gas;
    - Emissions from interstate transport and disposal of waste brines;
    - Emissions from interstate and/or international transport of proppant.
- The EMP completely fails to engage with the contribution which Tamboran's exploration and appraisal program will make to climate change, and the manner in which Tamboran's activities will exacerbate climate change-related harms which are already impacting ecosystems and communities in the NT.

The EMP states that beneficial use of gas is not part of the current proposal and indicates that an amendment to the EMP will be sought if it decides to proceed down this path, citing cost uncertainty. And yet, the estimates of greenhouse gas emissions from the site beyond 2025 assume that this will be the case and rely on beneficial use to reduce direct emissions to below the Safeguard Mechanism threshold after 2025. As a result, the estimate of 400,000 tonnes of greenhouse emissions over four years cannot be relied upon by the decision-maker in assessing this application and must be revised. Using the proponent's estimate of an 80% reduction in emissions after 2025 should this project proceed, actual emissions from this exploration and appraisal program

without the speculative "flare avoidance program" could be as high as 1.1 million tonnes. If the proponent is not in a position to commit to the program, then two separate emissions assessments should be provided, with and without the program.

The EMP fails to assess "all the environmental impacts and environmental risks arising directly or indirectly from all aspects of the regulated activity" (per Sch 1, s 3(2)(a)(i)), because:

- The downstream or "Scope 3" emissions associated with appraisal gas envisaged to be sold under the "flare avoidance program" are omitted from the emissions assessment;
- The estimate of emissions arising from the flaring of produced gas is based on unrealistic and unjustified assumptions about the efficiency of gas flares;
- Neither the known uncertainty in the additionality achieved by Australian Carbon Credit Units (anticipated to be deployed to offset "residual" emissions associated with the program) nor the environmental impacts of generating ACCUs are assessed in the EMP;
- The EMP refers to a "similar (but different) unconventional gas development" to assert the alleged "net climate benefits of using natural gas in replacing coal for electricity," without any evidence as to either the application of the cited study to the Beetaloo shale context or the actual likelihood of Beetaloo gas replacing coal in its eventual use scenario.

The EMP further fails to assess "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity" as required by Sch 1, s 3(2)(b), because:

- The recent and anticipated emissions from other proponents' gas appraisal activities in the Beetaloo and broader McArthur Basin area are not included in the cumulative emissions assessment;
- The clearly foreseeable scope 1 emissions impact of the construction of infrastructure required to support a shale gas industry in the Beetaloo – the end goal of Tamboran's exploration and appraisal program – is not included in the cumulative emissions assessment;
- The clearly foreseeable scope 3 emissions impact of the combustion of gas sold from Tamboran's anticipated production of onshore gas in the Beetaloo is not included in the cumulative emissions assessment.

No mention is made in the summary in Table 8 of regulatory requirements of the NT's Major Emitters Policy. The major emitters policy applies to "all new projects and expanding existing projects likely to be large emitters that occur after commencement of this policy and which are required to obtain an environmental authorisation under Territory legislation to proceed." The threshold for the major emitters policy is similar to the Safeguard Mechanism: Estimated scope 1 emissions of 100,000t$CO_{2\text{-}e}$ in any financial year over the life cycle of a project, not counting emissions generated from land clearing directly associated with the project. The major Emitters policy requires proponents to develop and implement a greenhouse gas abatement plan (GGAP) *that has been tailored specifically for their project*. No such plan has been provided.

Additional detail about some of the identified issues with the EMP is provided below. As a result of these omissions, we submit that the Minister cannot reasonably be satisfied that the EMP meets the approval criteria under the *PE Regulations*, and cannot lawfully decide to approve the EMP.

Referral to the NT EPA for potential significant impact of greenhouse emissions

Further, we submit that the estimate of the emissions resulting from the project – even with the omissions we have identified – indicates that the E&A program has the potential to have a "significant impact" requiring referral to, and consideration by, the EPA. Tamboran states that it has "completed a self-assessment" and determined that the "level of potential environmental impact is not considered significant," and therefore that the program does not require referral to the EPA (page 30).

According to the EMP, the "potential (residual- not offset) emissions" from its activities "represent 1.35% of the total NT GHG emissions for 2021" (p 125 of the EMP). This appears to refer to the volume of emissions forecast for the project provided in Table 23, which assumes that the "flare avoidance program" will be implemented by FY2026 and FY2027. It is claimed that this program would reduce emissions in those years by 80%. Accordingly, the emissions impact of the exploration and appraisal activities should the "flare avoidance program" *not* be implemented, would be significantly higher. In 2026, the 98,115 tonnes estimated in the EMP would be 490,575 tonnes, or nearly 3.5% of Territory emissions in 2021.[14] In 2027, the 86,395 tonnes cited in the EMP would in fact be 431,975 tonnes. The total for all four years of operation could potentially be as much as 1.14Mt in total. Given the flare avoidance program is not described or committed to in the EMP, the regulator must assess the proposal based on the actual emissions it will create, which represent a significant impact on the environment and people of the NT.

The threshold for the application of the NT's Large Emitters Policy to onshore gas activities is total emissions from all a proponent's activities for a financial year exceeding 100,000t CO_2-e. In guidance prepared by the NT EPA about when projects may require referral to the EPA, emissions reaching this threshold are included as a basis for the project being referred to the NT EPA.[15] Similarly, this threshold also triggers inclusion in the Safeguard Mechanism (SM).

Accordingly, Tamboran's E&A program meets a stated criterion for referral to the NT EPA, under *either* the "flare avoidance program" scenario that has been assumed for the program's emissions estimate, or the far more likely much higher emissions scenario that would occur in the absence of appraisal gas being sold. Even if Tamboran's assertion that the emissions from the program represent 1.35% of the NT's emissions is accepted, this is still, put in perspective, a significant impact. An emissions profile equivalent to over 1% of the Territory's entire emissions created by just one set of appraisal activities by just one company operating in just one industry over just four years is significant, and any attempt to paint it otherwise is misleading and incorrect.

We note that the EMP has invoked a "life cycle assessment" of greenhouse emissions from unconventional gas development in its greenhouse gas discussion (p 134). We welcome this admission that the lifecycle emissions of the proposed activity are a relevant consideration for the decision maker. Indeed, consideration (and offsetting) of lifecycle emissions is implicit in Recommendation 9.8 of the Fracking Inquiry, which is yet to be implemented. It is misleading,

[14] Australia's National Greenhouse Accounts – UNFCCC emissions (AR4) <https://greenhouseaccounts.climatechange.gov.au/>.

[15] See NT EPA, 'Referring a proposal to the NT EPA: Environmental impact assessment guidance for proponents) (24 August 2022), p 24.

however, for the EMP to present lifecycle emissions *only* in comparison to lifecycle emissions of coal-fired electricity, given that coal production and use is not underway in the Northern Territory, and to invoke speculative other possible means by which the unacceptable and dangerous greenhouse gas emissions from this activity and others like it might, or might not, be mitigated.

Further details of issues in the EMP's greenhouse gas emissions risk assessment

The flare avoidance program

The fundamental problem with the treatment of the proposed "flare avoidance" (or appraisal gas use) program in the EMP is that the company has at once assumed that the program will be deployed, presenting the emissions impact of the program solely on that basis (see Table 23, p 120), while at the same time outlining cause for deep uncertainty as to the actual deployment of that program, *and* failing to acknowledge the other emissions that would arise from its implementation. This gives a critically misleading picture of the E&A program's climate impact.

As Tamboran partially acknowledges in the EMP, the sale of appraisal gas is subject to:

- under section 57AAA of the *Petroleum Act 1984* –
    - approval by the Minister, in line with the conditions set out in s 57AAA(5)(a)-(c), and
    - the approval, consent or agreement of Traditional Owners under the *Aboriginal Land Rights Act* or Native Title;
- the approval of an additional EMP or EMP amendment under the PE Regulations covering the appraisal gas sale or use;
- the decision to invest in the construction of costly appraisal sales infrastructure; and
- securing purchase agreements for produced gas.

Clearly, the implementation of the flare avoidance program is subject to considerable uncertainty and the EMP has failed to accurately describe both the impacts of it proceeding and the impacts of it not proceeding.

Tamboran has not provided a baseline estimate of the emissions that would be expected to occur in the absence of the flare avoidance program, even though – given the various obstacles standing in the way of the flare avoidance program being deployed – that baseline scenario is currently the one most likely to occur. On the other hand, if Tamboran assumes that the flare avoidance program is implemented – as it has in the emissions profile presented in the EMP – then the *other emissions associated with that program need to be included as well*. In either case, the EMP does not provide an assessment of all the environmental impacts of the proposed activities, as is required under the *PE Regulations*. Such additional emissions would include the construction of the appraisal gas processing and transport infrastructure, fugitive methane and other emissions from that processing and transport, and the combustion of the appraisal gas – whether by Tamboran under an on-site "beneficial use" scenario, or by other consumers downstream.

Underestimation of emissions from flaring

Tamboran asserts (without citing any sources) that the combustion of produced gas through flaring "will reduce the emissions generated by flaring by 94% when compared to venting" (see p 120). Tamboran has assumed a flare efficiency of 98% elsewhere in the EMP (see Table 1, p 7).

This 98% efficiency assumption for gas flares is based on highly outdated data from the US EPA, and does not accord with more recent and comprehensive studies.[16] Research published in 2022 found that gas flares were effectively destroying only 91.1% of the methane diverted to the flares from three gas fields in the US.[17] The IEA considers that the actual efficiency of gas flares used by the industry worldwide is approximately 92%.[18]

The Methane Emission Management Plan provided by Tamboran at Appendix I to the EMP does not refer to any strategy to ensure flaring at the Shenandoah South site that will actually operate at the 98% efficiency assumed for the purpose of the EMP's emissions estimate. Accordingly, this aspect of the E&A program's emissions impact is not reliable and, given the potency of methane's atmospheric warming effect compared to CO_2, probably underestimated.

Uncertain emissions avoidance achieved by Australian Carbon Credit Units

There are two major issues with Tamboran's proposal to use carbon credits to offset emissions resulting from its E&A program.

Reliance on the preservation or growth of vegetation as an equivalent compensation for the release of carbon or methane from fossil fuel use has long been the subject of controversy and will increasingly be the target of regulatory and finance constraints given the urgency of abatement and the increasing volatility of the climate, with flow-on implications for the impermanence of carbon stored in soil and vegetation.

Tamboran relies on its unreliable emissions calculations and deductions from the uncommitted flare reduction program to argue that this program will be responsible for emissions above the Safeguard Mechanism threshold in one of its four years of operation. The EMP correctly cites a zero baseline for all new shale gas activities in the Safeguard Mechanism, but fails to discuss the likelihood that this activity will emit above the Safeguard threshold for three years, requiring either aggressive emissions abatement activity on Tamboran's part, or wholesale purchase of offset credits, either Safeguard Mechanism Units or ACCUs in the order of 900,000 tonnes over three years. Furthermore, the company proposes an emissions reduction obligation (or rather, an offset purchasing obligation) on the activity of 3.7% cumulatively per year, applying the Safeguard Mechanism zero baseline only in the second year of operation. There is no discussion of the company's ability to source sufficient offsets to meet this commitment, nor the prospect of having to meet a far higher abatement

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[16] See World Bank – Global Gas Flaring Reduction Partnership, "Why are flares a source of methane emissions?" (accessed 19 December 2023) <https://www.worldbank.org/en/programs/gasflaringreduction/methane-explained#SourceOfMethane>.
[17] Genevieve Plant et al, 'Inefficient and unlit natural gas flares both emit large quantities of methane' (29 September 2022) 377(6614) Science 1566 < https://www.science.org/doi/10.1126/science.abq0385> .
[18] International Energy Agency, 'Gas Flaring – CO2 emissions' (accessed 19 December 2023) <https://www.iea.org/energy-system/fossil-fuels/gas-flaring>.

requirement should the activity emit above the Safeguard Mechanism threshold in the final two years of operation. We note that on 19 December, the company published its first report against the Taskforce on Climate-related Financial Disclosure guidance, committing to "net zero" operations once commercialised. This commitment is contrary to the regulatory requirements established by the Safeguard Mechanism, which does not distinguish between commercial production and exploration activities - all shale gas activities have a zero baseline and this project is not proposing to achieve that.

We note too, that the TCFD report indicates that "Tamboran has been progressively buying carbon offsets since 2021. As of December 2023, Tamboran has over 51,000 carbon offsets in its portfolio and has contracted 60,000 more carbon offsets to be delivered from 2024 to 2025."[19] The actual emissions from this activity in its second two years could create in the order of 900,000 tonnes of greenhouse gas emissions which would all need to be avoided or offset under the terms of the Safeguard Mechanism.

Failure to describe the project's contribution to climate change and related harms

In order to comply with the *PE Regulations*' requirements to describe and assess all environmental impacts arising from the activities proposed, Tamboran should have, in this EMP, presented an assessment of the impacts further emissions of greenhouse gases will have on the climate, and the flow-on impacts of climate change on the Northern Territory's environment. Indeed, the *EP Act 2019* requires the consideration of the impacts of a changing climate during the environmental impact assessment of a project to inform the decision on an environmental approval for that project

However, despite listing (some of) the emissions that will be created by its project, Tamboran does not at all describe how these emissions will contribute to global climate change, nor how climate change will impact on the ecosystems and communities of the NT.

Climate change impacts are already being experienced across the Northern Territory. Core impacts identified by the NT Government include:

- A significant increase in the number of extremely hot days, both in the Top End and central Australia;
- The intensity of heavy rainfall events has increased and will continue to increase;
- Droughts are likely to be more severe and more extreme fire behaviour is expected;
- More intense tropical cyclones; and
- Higher sea levels and temperatures.

Fossil fuel extraction and use, like that proposed by Tamboran in this EMP and in its broader Beetaloo development plan, is the foremost cause of climate change. If fossil fuel extraction and use continues, including through developing the Beetaloo, there is a real and tangible risk - if not an inevitability - that large parts of the NT will be unlivable in a matter of decades.

[19] Tamboran Resources. *TCFD Climate Change and Net Zero Report*. December 2023.

None of the established impacts of climate change, directly relevant to the greenhouse gas emissions from the project and from developing the Beetaloo, are described or assessed in the EMP. This, again, constitutes a failure to comply with the requirements in Schedule 1 of the PER.

Referral to the EPA needed

This proposal has not been submitted to the EPA for assessment by the proponent itself. You, as the relevant decision maker, have the power to refuse to consider the application until the action is referred to the NT EPA and a decision is made on referral. Section 50 *Environment Protection Act 2019* states:

> *50 Referral if application made to statutory decision-maker*
>
> *(1) This section applies if a proponent applies to a statutory decision-maker for authorisation of a proposed action and the decision-maker considers that the action should be referred to the NT EPA under this Division.*
>
> *(2) The statutory decision-maker:*
>
> *(a) may refuse to consider the application until the action is referred to the NT EPA under this Division and a decision is made on the referral; and*
>
> *(b) must take all reasonable steps to encourage the proponent to refer the action to the NT EPA; and*
>
> *(c) may refer the action to the NT EPA.*

The proponent, in its EMP states claims: "Tamboran has completed a self-assessment. The level of potential environmental impact is not considered significant." The Department must encourage the proponent to refer the action to the EPA, or refer this activity to the EPA itself as per s50 of the *Environment Protection Act 2019*. Given the scale and magnitude of the regulated activities being proposed, including land clearing, exploration through fracking, penetration of important regional aquifers with the potential for inter-aquifer connection should well barriers fail, complex wastewater management systems and hazardous chemicals handling. Each of these activities which have the potential to cause a significant impact to the environment are required to be referred to the EPA for assessment under the *Environment Protection Act 2019*.

Referral under the EPBC Act required

We are not aware of the proponent referring this activity to the Commonwealth for assessment and decision under the *EPBC Act*. The proponent claims with regard to EPBC Act that "A self-assessment was completed as a part of this EMP to determine whether a MNES is likely to be impacted by the proposed activities within this EMP. Impacts to MNES are not anticipated to occur." In December 2023, amendments were passed extending the application of ss24D and 24E of the *EPBC Act* to all unconventional gas. This proposal must be referred to the Commonwealth for assessment under the water trigger, as well as for its impacts on nationally threatened species.

Conclusion

Lock the Gate Alliance objects to this proposed exploration and appraisal program. The EMP submitted to the Department contains incomplete, inadequate and misleading information but there is sufficient evidence to indicate that it will have unacceptable impacts on the environment and people of the Northern Territory. We urge the Department and the Minister to reject this proposal.



Shale Gas Drilling with the Helmerich & Payne Flex 3 Rig in the Beetaloo Basin, Northern Territory, Australia

23 December 2023

Daniel J. Soeder, Soeder Geoscience LLC

Soeder Geoscience LLC

We rock!

Disclaimer

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Cover Illustration: Mast and a stand of drill pipe on a BOSS super-spec rig drilling in the Niobrara Formation of eastern Colorado, USA. This drill rig is similar to the Helmerich & Payne super-spec Flex 3 Rig. Photo taken in 2016 by Dan Soeder.

Shale Gas Drilling with the Helmerich & Payne Flex 3 Rig in the Beetaloo Basin, Northern Territory, Australia

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23 December 2023



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Glossary of Terms

Term	Description
annulus	Ring shaped space between the drill or casing string and the borehole wall.
bit	The cutting implement on a drill
bitumen	Early-stage oil, thick and tarry
breakdown	The pressure at which rock strength yields to a frack; fracture initiation.
casing	Protective steel pipe inserted in a well and cemented in place
condensate	Light hydrocarbons produced as vapors that condense to liquids at the surface.
conventional	Hydrocarbon production from a traditional reservoir rock with trap and seal.
cuttings	Sand-sized particles of rock created by the cutting action of a drill bit.
derrick	The mast or tower above a rig used for holding lengths of drill pipe
DOE	U.S. Department of Energy
doghouse	Trailer or hut mounted on a drill rig from where the driller operates the rig.
dope	Lubricating compound placed on drill pipe threads.
drill rig	Equipment used to construct wells for water, oil, and gas.
drill string	Multiple joined segments of drill pipe with a bit on the end.
driller	The person who operates the drill rig and is responsible for the well.
flowback	Frack fluid returned to the surface post-frack by produced gas pressure.
frack	Spelled “frac” by industry. Slang term for hydraulic fracturing.
geophones	Microphones that pick up the sound of breaking rock to triangulate the position of a hydraulic fracture through microseismic monitoring.
geosteering	The art and science of keeping a directional borehole on course.
joint	A single length of drill pipe, 10 meters long and threaded on both ends.
heel	The curved borehole between the vertical tophole and the horizontal lateral.
induced seismicity	Earthquake triggered by the injection of fluids into the ground; can occasionally be caused by hydraulic fracturing but more likely by wastewater disposal.
kerogen	Early-stage hydrocarbon substance derived from buried plants
lateral	A horizontal borehole through a target formation.
mud	Fluid made of water, clay and chemicals used to cool the bit and remove cuttings.
mud logger	A geologist (usually) who collects drill cuttings to track progress of the borehole.
NDA	Non-disclosure agreement to keep something confidential.
packer	An inflatable, donut-shaped rubber bladder around a string of casing used to seal off and isolate parts of a borehole.
pancake	A too-shallow frack that breaks the rock horizontally instead of vertically.
PDC bit	Polycrystalline diamond composite; a drill bit designed specifically for shale.

Glossary of Terms (cont.)

Term	Description
perf gun	Explosive array used to create holes in ("perforate") the production tubing
produced water	Formation water, usually salty, produced with oil and gas.
production tubing	Long string of casing from the surface to the producing formation in a well.
proppant	Granular material such as sand emplaced in a fracture to prop it open after the hydraulic pressure is released.
reservoir rock	A porous and permeable rock with a trap and seal to hold hydrocarbons.
roughneck	Term for the crew of a drill rig, especially the manual laborers.
shale shaker	A series of vibrating screens that remove the cuttings from the returned mud.
slickwater	A low-friction fluid made from water and polyacrylamide.
source rock	An organic rich rock with sufficient thermal maturity to create oil and gas
spud	The initial penetration of the ground surface by a drill bit.
stage	A segment of lateral, usually 150 m long, perforated and fracked in a shale well.
stimulation	An action or process such as an acid treatment or hydraulic fracturing to induce a reservoir to produce oil and gas.
stranded gas	Gas resources in a region lacking transmission pipelines
TD	Total depth (of a drill hole)
TDS	Total dissolved solids (in water)
TOC	Total organic carbon
toe	The end, tip, or farthest extent of a lateral.
tool pusher	Term for a drilling program manager who may be responsible for multiple rigs.
tophole	Vertical borehole from the surface to the curve where the lateral starts.
trip	The act of inserting (trip in) or removing (trip out) drill pipe from a borehole
UIC well	Underground Injection Control well; a permitted disposal well in the U.S.
unconventional	Hydrocarbon production directly from a source rock
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOCs	Volatile organic compounds; light hydrocarbons forming condensate

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The author acknowledges having read the Code of Conduct from the Northern Territory Supreme Court for Practice Direction No 6 of 2015: Expert Reports and agrees to be bound by it.

Qualifications

Daniel J. Soeder, the principal consultant at Soeder Geoscience LLC has over 40 years of professional experience with energy and the environment. This includes a decade as a researcher at the Gas Technology Institute in Chicago, 18 years as a hydrologist with the U.S. Geological Survey (USGS) on both nuclear waste isolation and water resources in the eastern U.S., and eight years as a research scientist at the National Energy Technology Laboratory of the U.S. Department of Energy (DOE). He spent five years as a DOE representative on an interagency group that was charged with assessing the environmental impacts of U.S. shale gas development. He also spent three years directing an energy resource program at the South Dakota School of Mines & Technology before founding his consulting company in 2021. Mr. Soeder has a long research publication record beginning in the 1980s and extending to the present day. A paper he published in 1988 indicated that the gas potential of the Marcellus Shale was substantially greater than assumed at the time and was proven right twenty years later when the Marcellus became the largest gas-producing formation in the world. This publication is now considered a foundational study for shale gas. His recent publications have been focused on the shale gas - tight oil revolution, the effects of fracking on the environment, and a book for non-scientists that explains the scientific relationships between fossil fuels, greenhouse gas, and climate change. He holds BS and MS degrees, both in geology. He is also an adjunct instructor at West Virginia University where he teaches petroleum geology.

Daniel J. Soeder is the sole author of this report and all opinions expressed are his alone.

EXECUTIVE SUMMARY

The Velkerri Formation in the Beetaloo basin of the Northern Territory of Australia has been targeted for gas production by Tamboran Resources Limited. The unit of interest to Tamboran is the Amungee Member, which is the middle unit of the Velkerri Formation. It consists of an organic-rich, black shale that contains significant gas. A vertical well 3,300 meters deep has been drilled to reach the formation, and a horizontal lateral 1,000 meters long is planned to produce the gas.

Tamboran Resources has procured the services of a Helmerich & Payne (H&P) super-spec FlexRig Flex 3 drill rig to drill wells into this shale. The H&P is a large, modular drill rig model designed and engineered specifically for optimal performance in shale. It can drill horizontal wells with a bottomhole assembly that includes a motor powered by hydraulic pressure, and a steerable bit to directionally drill lateral boreholes in shale. Because the shale wells are directional, multiple wells can be expected on each well pad. The "super-spec" rig is capable of slowly "walking" to a new position on the pad to drill additional boreholes without being disassembled and reassembled.

Environmental impacts from the H&P rig *per se* appear to be no more significant than similar risks from any other oil and gas operation. The rig is specifically designed for use on shale gas resources, and rigs like this have been used in the U.S. for over a decade without major problems. Nevertheless, any type of shale gas development in the Beetaloo basin will impose some environmental risks. Air quality may suffer from fugitive emissions or as toxic dust from dried out evaporation ponds is carried by the wind. Landscapes may be altered by the two hectare-size well pads. Habitats may be isolated by cross-cutting service roads and pipeline rights-of-way. Invasive species may hitch rides on drill rigs or the vehicles of workers coming in from great distances. Water supplies in this semi-arid scrubland may be affected by the water demands of high volume hydraulic fracturing. Surface water and groundwater may be contaminated by chemical spills, produced fluids, or leachate from shale cuttings. If the vertical part of the well is drilled with air, there could be groundwater impacts.

An over-riding environmental concern is the justification for any new fossil fuel development in a greenhouse gas-heated, climate-challenged world. Tamboran claims that the gas will substitute for coal in the domestic power generation sector, thereby cutting Australia's emissions. Natural gas combustion does emit less carbon dioxide than coal, but this can be negatively offset by the fugitive emissions of methane (an even more powerful greenhouse gas) leaking from the gas transmission and distribution system. The industry should be challenged to perform a lifecycle analysis and place some actual hard numbers on this claim.

It is possible to develop shale gas in the Beetaloo basin with minimal, manageable environmental impacts. It requires a professional operator who is willing to mitigate environmental risks as much as possible by following best practices, along with diligent monitoring by an outside, independent entity.

1. INTRODUCTION

The Beetaloo basin (figure 1) in the Northern Territory of Australia has recently become the focus of shale gas development by Tamboran Resources. The Beetaloo is a small rift basin with an area of about 36,000 square km located approximately 650 km southeast of Darwin. It is bounded by the Walton High to the north, the Helen Springs High in the south, and the Batten Trough in the east, with its western margin projected to extend to the Daly Waters Arch[1].

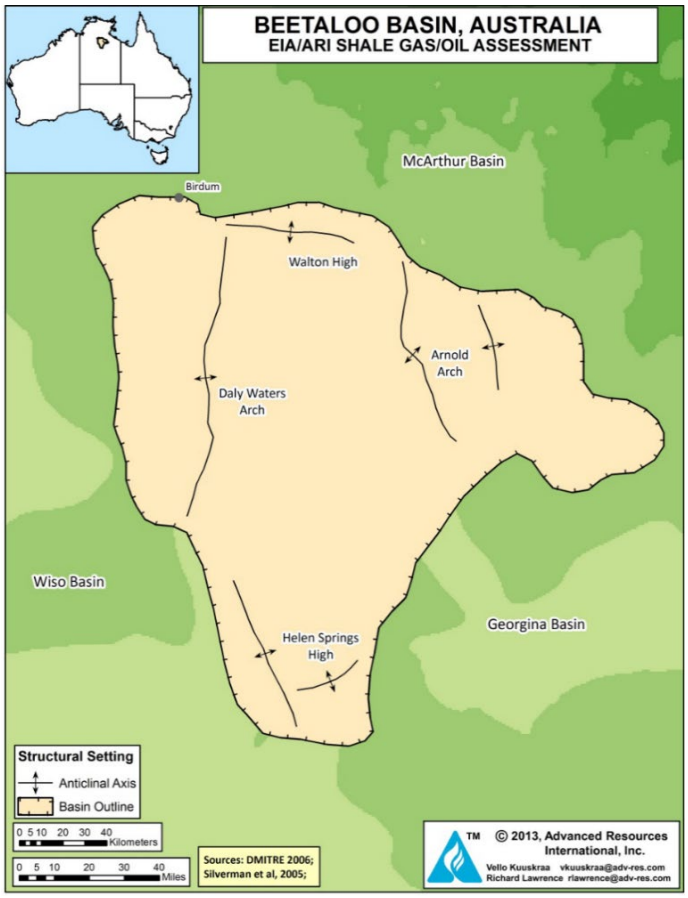


Figure 1: Location map of the Beetaloo basin in the Northern Territory of Australia (USEIA, 2013).

Target shales in the Beetaloo basin are the Kyalla Formation and the slightly deeper and older Velkerri Formation. Both of these shales are members of the Roper Group and are Mesoproterozoic (Precambrian) in age. At around 1.4 billion years old they are some of the oldest hydrocarbon source rocks in the world. This report will describe how gas is produced from shale, and then focus on the potential environmental impacts to water resources, landscapes and habitats, air quality, and ecosystems including human health. The questions provided by the EDO are addressed throughout the document and specifically in the last section.

[1] U.S. Energy Information Administration and Advanced Resources International, 2013: Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries outside the United States. U.S. Department of Energy, Washington, DC, 730 p.

2. GEOLOGY

The Velkerri Formation in the Beetaloo basin consists of organic-rich black shales interbedded with gray-green, organic-lean shales and thin siltstone and sandstone units. The primary production target is the middle Amungee Member, a marine shale deposited in shallow to moderately deep water. This unit contains an average total organic carbon (TOC) content of 4%, but this can get as high as 12% in some locations. The organic matter is composed of Type I and II kerogens, both of which are oil prone. The upper and lower Velkerri Shale units contain less than 2% TOC and are not considered productive. The potentially productive area of the Amungee Member ranges in depth from less than 1 km on the Walton High to about 3 km in the basin center. The organic-rich part of the middle Velkerri Shale averages about 30 meters thick across the basin[2] although a greater than average thickness was reported by Tamboran at their targeted location.

The Kyalla Formation overlying the Velkerri Shale has upper and lower shale sections separated by a thin sandstone. The lower Kyalla Shale is considered potentially productive, but it is leaner in organic matter compared to the Velkerri Formation. The most organic-rich sections of the lower Kyalla Shale in the basin center contain TOC values as high as 9%, but the average TOC of the shale overall is just 2.5%. Thus, Tamboran Resources is focused on the deeper Amungee Member of the Velkerri Shale (figure 2).

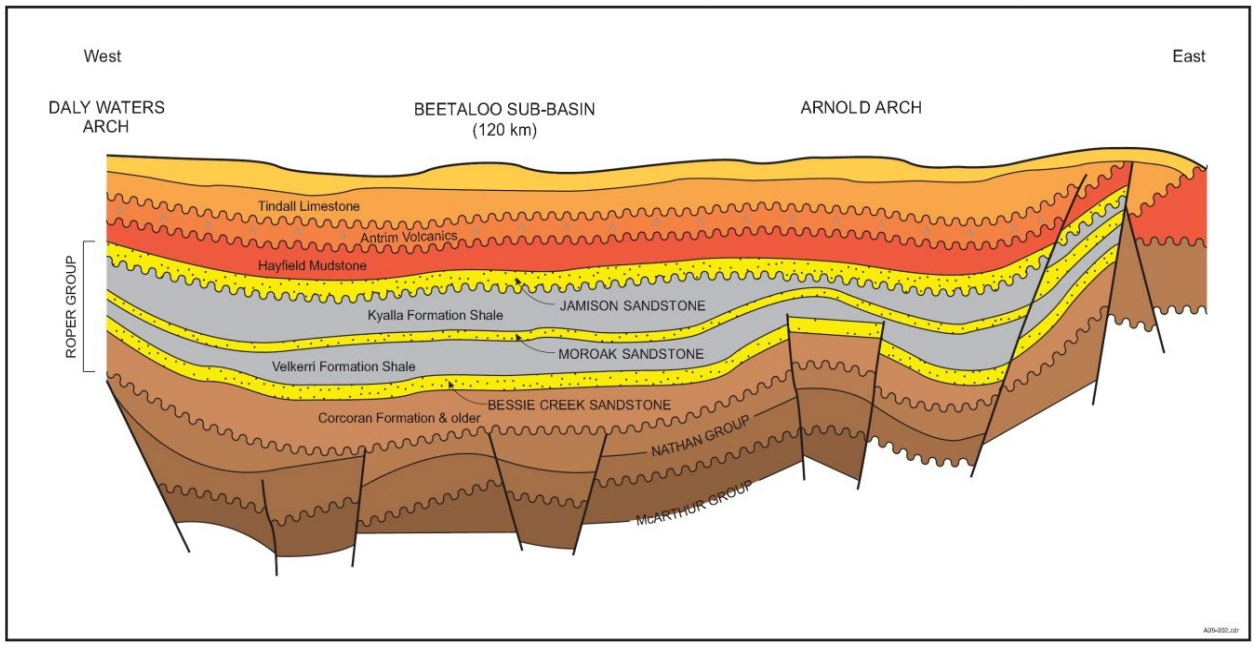


Figure 2: West to east cross section of the Beetaloo basin showing the Velkerri Shale and the overlying Kyalla Formation[3].

[2] Warren et al, 1998: Proterozoic Source Rocks: Sedimentology and Organic Characteristics of the Velkerri Formation, Northern Territory, Australia: *AAPG Bulletin*, V. 82, No. 3, P. 442-463

[3] Ambrose and Silverman, 2006, Onshore Hydrocarbon Potential of the Beetaloo Sub-Basin: Northern Territory Geological Survey, Record 2006-003.

The Tamboran Resources "operational update" news release dated 30 August 2023 and provided by EDO in the reference documents noted that the Shenandoah South 1H well had intersected 90 meters of middle Velkerri Shale with strong dry gas shows at a total depth (TD) of 3,300 meters. The release states that this is the thickest section of this unit found in the Beetaloo basin to date, and the next phase will be to drill a one km long lateral for ten stages of hydraulic fracturing.

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A brief and simplified explanation of some petroleum geology concepts may be helpful for readers who are unfamiliar with how natural gas and oil (and coal) are created. Virtually all fossil fuels are derived from ancient plants, not dead dinosaurs as some people think. Dead plants are deposited in quiet water settings along with fine-grained muds and silts that eventually harden into shale or limestone. Higher water energy environments that deposit sand and gravel are not usually conducive for preserving plants. The plant deposits are covered by fine sediment and subjected to heat and pressure in the absence of oxygen as the sediments are buried ever deeper by more material piled on top. The plant matter is converted into a precursor hydrocarbon called kerogen, which comes in three varieties: Type I is a waxy substance formed primarily from fresh water algae. Type II is an oily material formed from marine algae and some soft terrestrial plant components like leaf cuticles. Type III is a cellulose-rich compound created from woody terrestrial plants. All three types of kerogen can generate methane, which is the primary component of natural gas. Types I and II will also generate petroleum. Type III forms coal.

Thermal maturity defines the types of hydrocarbons generated from the kerogen. Coal goes through different "ranks" depending on how much heat and pressure it was exposed to over geologic time. These range from soft, brown coal called lignite up to rock-hard, glassy black coal called anthracite. Petroleum also goes through various changes with thermal maturity called "windows." The lowest level of thermal maturity creates the oil window, starting out with a thick, tarry substance known as bitumen composed of long-chain hydrocarbons. At increased thermal maturity, long hydrocarbon chains break apart or "crack" and form lighter oils. As temperatures get higher, the petroleum moves into the "condensate" window, also known as "wet gas." This is composed of volatile organic compounds (VOCs) such as propane and butane that exit the well as vapors and condense into liquids at the surface (hence the name). The highest thermal maturity window is dry gas, where complex hydrocarbons break down into thermogenic methane, the simplest and most stable hydrocarbon. At low temperatures, biogenic methane is produced as a metabolic byproduct by microbes feeding off organic matter in the sediments. Both types of methane gas can be present in a rock.

The fine-grained shale or limestone where the organic matter was deposited are called "source rocks" and have not traditionally been targeted for production. Oil and gas were produced historically from "reservoir rocks," such as porous and permeable sandstone formations. A migration pathway was necessary for the hydrocarbons to travel from the source rock to the reservoir rock. The reservoir rock also needed a trap and seal to contain the oil. It is not too hard to imagine that traditional oil and gas exploration was largely a hit or miss affair, yet nearly all of the oil and gas produced in the 20th Century came from these "conventional" reservoirs. The big breakthrough with shale gas and tight oil in the 21st Century was the development of technology that could produce hydrocarbons directly from the source rock. This type of production is called "unconventional." A substantial amount of oil and gas in the U.S. and increasingly worldwide is now obtained from unconventional resources.

3. DRILLING IN SHALE

The production of oil and gas is a profession, and many participants have been at it for years, if not decades. Like most professions, the practitioners have a unique vocabulary, and it is important for those who wish to interact with them to understand the terms being used. People who try to talk to industry personnel without using the proper language are immediately seen as non-experts or outsiders and dismissed. In the words of industry people, they are unable to carry on an "adult conversation" and not taken seriously. This is true in many professions, not just oil and gas. For example, if someone chooses to act as their own counsel in a court of law, but doesn't know the meaning of terms like testimony, deposition, compensatory versus punitive damages, plaintiff, defendant, etc., their words are not likely to carry much weight with legal professionals or a judge.

Before getting into a description of how shale gas is produced, a brief primer on oil and gas terminology is warranted. For starters, oil and gas wells are drilled, not "dug." People hand-dug shallow water wells up until the early 20th Century, but just about all wells these days are drilled. Wells are drilled using a drill rig; these vary in size, but the general rule is the deeper the well, the bigger the rig. There are some old-fashioned percussion rigs still in use called "cable tool rigs" that basically pound a hole into the ground, but most modern drill rigs are rotary, and use a spinning drill bit to cut into the rock. The bit must be cooled to keep from burning up due to friction and the small chips of rock or cuttings created by the drilling have to be removed from the hole. This is accomplished by injecting a fluid through and across the bit to carry away heat and cuttings. The fluid can be compressed air or water, but on an oil and gas drilling rig it is more likely to be a substance known as drilling mud, often just called mud. The mud is a slurry of clay, water, and a variety of specialty chemicals that serves three functions: it cools the bit, it brings the cuttings back up to the surface, and it offsets rock pressure to keep the borehole walls from collapsing and oil or gas from entering the well prematurely. The mud is stored at the well site in a lined mud pit, and it is pumped downhole with a mud pump.

The drill bit is attached to the end of a length of pipe called the drill string. The pipe is made up of segments called joints that are nominally 10 meters long and threaded on both ends. As the bit deepens the hole, new joints are added to the upper end of the drill string after being lubricated with a substance called pipe dope to keep the threads from gouging. The initial penetration of the ground surface with the bit is called the spud. The date of the spud is considered the actual start date of drilling the well. The drilling is finished when the borehole reaches the planned total depth, usually abbreviated TD. The mud is pumped down the inside of the drill string to the bit. It flows out through holes in the bit to cool it, picks up cuttings in the bottom of the well and returns to the surface through the annulus, which is the ring-shaped space between the drill string and the borehole walls. At the surface, the mud is run through a series of vibrating screens called the shale shaker that separates out the cuttings before it returns to the mud pit for re-use. A member of the rig crew called the mud logger periodically collects the cuttings off the shale shaker, cleans them and performs a quick examination under a binocular microscope to determine the formation from where they were cut. Most mud loggers are geologists who run a continuous log of the geology from the cuttings and track the progress of the borehole from rock unit to rock unit. The person who operates the rig is called the driller, and they are assisted by two or three rig hands known as roughnecks. A frequent visitor to the well site is the drilling manager, called the tool pusher, who is often responsible for multiple drill rigs and spends a lot of time going from location to location.

If the bit wears out or they have to remove the drill string from the hole for any other reason, the process is called a trip, or in this case, tripping out. Once the bit is replaced, they will trip back in and

continue drilling. Land rigs are classified by the height of the derrick or mast, which defines how many joints of drill pipe can be tripped from a borehole in a single stroke. A small drill rig that can only trip one joint at a time is called a single. A bigger rig capable of tripping two joints is a double, and huge rigs like the Helmerich & Payne (H&P) super-spec FlexRig Flex 3 are known as triples. The advantage of being able to trip three joints at a time out of a borehole is that it can be done more quickly. The drill pipes have to be separated at the joints, and if three segments can be left together after tripping out it reduces the number of joints that have to be unscrewed. On deep holes where one might be tripping out kilometer-long drill strings, this can make a significant difference in time and effort.

While single rigs are typically truck-mounted and manually operated, most modern double and especially triple rigs are powered by electric-hydraulic systems, using a bank of on-site generators to provide electricity for the rig's hydraulics. Manual tasks like handling and threading together individual joints of drill pipe using chain wrenches and other hand tools has mostly been taken over by machines. Some double rigs are truck or trailer mounted but large triple rigs like the H&P are modular and are assembled on-site from the components. Shale gas development requires specialized drill rigs, downhole tools, and support equipment. The H&P Flex 3 rig was specifically designed for shale gas production.

As the well is drilled, steel pipe called casing is placed in the borehole. Lengths of casing are also called strings (like the drill pipe), and larger diameter casing strings are emplaced at the surface, with narrower strings going to depth. The casing is held in place by cement pumped into the annular space between the steel pipe and the borehole walls. Casing serves multiple purposes. The first string, called surface casing, generally goes down a hundred meters or so and is designed to keep drilling mud and other fluids from contaminating shallow groundwater aquifers. The next string, called intermediate casing, is used to keep oil, gas, and saltwater from entering the well above the target formation and also supports the borehole walls against rock pressure. The narrowest string of casing that runs from the surface to TD is called the production tubing, and it is through this that oil and gas are produced from the target formation and brought to the surface.

Once the well is drilled and all the casing is set, it goes through a process called completion. This consists of creating holes in the deepest part of the production tubing so that hydrocarbons from the target formation can enter the well. The procedure is called perforating and the tool used is a perf gun. Actual bullets were used in the old days, hence the name, but modern perf guns used shaped charges of high explosive to blast a row of 1-2 cm diameter holes through the production tubing. In high-permeability, conventional reservoirs, perforating was often the final completion step, as oil and gas would flow freely into the well. Low permeability, unconventional rocks like shale need reservoir stimulation as an additional completion step. This can consist of a simple acid treatment to open up the perforations but in most cases it will involve hydraulic fracturing of the target formation. Reservoir stimulation will be discussed in greater detail in a later section.

In the old days, the rig crew typically consisted of the driller, who operated the rig with a throttle and a brake from inside a work trailer known as the doghouse. This was usually mounted on the rig floor so the driller could feel the vibration and adjust the RPM or rotations per minute. They literally drilled by the seat of their pants with almost no instrumentation. The rate of penetration was recorded on an analog device in the doghouse called a geolograph. Assisting the driller were three or four roughnecks who had the dirty job of connecting or disconnecting drill pipe joints, making sure there was drilling mud flowing down the drill string and back up the annulus, climbing up to the monkey board on top of the derrick when they were tripping out pipe to ensure that it was being properly

stowed in the pipe racks, and carrying out the 101 other duties needed to keep the rig running. There would also be a mud logger and visits from the tool pusher.

Shale gas is typically recovered in economic quantities by drilling a long, horizontal borehole at depth called a lateral through the target formation (figure 3). A lateral allows the wellbore to contact a large surface area of productive rock; far more than could be contacted by drilling vertically through the formation with a traditional well. The vertical thickness of these formations is generally just a few dozen meters, whereas a horizontal borehole can stay within the rock unit for kilometers. To produce the gas, a series of hydraulic fractures are emplaced at intervals along the length of the lateral. The hydraulic fractures are designed to create long cracks into the rock surrounding the borehole, providing high permeability flow paths to allow gas from distant areas of the formation to reach the wellbore and be produced. This production technique was developed by George Mitchell of Mitchell Energy on the Barnett Shale in the Fort Worth basin near Dallas, Texas, USA in the 1990s. Mitchell's technique was soon picked up by other drillers, and he became responsible for the so called "shale gas revolution" that followed in the early 21st Century[4]. In the United States, nearly three quarters of natural gas production now comes from shales, as does more than half of domestic oil production.

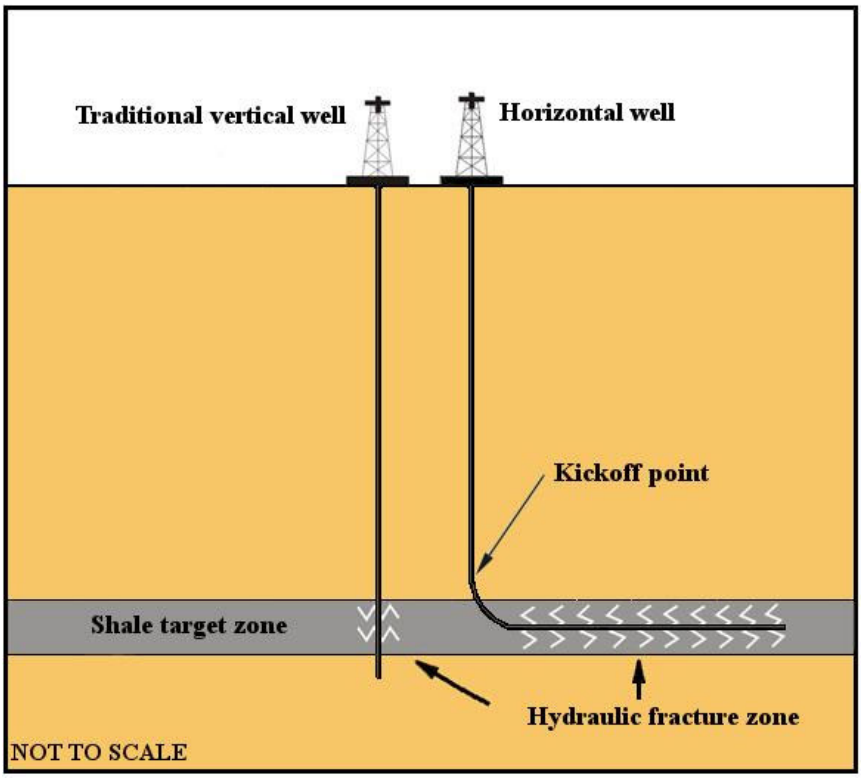


Figure 3: Schematic comparing the configuration of a conventional vertical well with a horizontal shale well[5].

[4] Soeder, D.J. and Borglum, S.J., 2019, The Fossil Fuel Revolution: Shale Gas and Tight Oil: Cambridge, MA: Elsevier Publishing, 336 p.

[5] Figure from Soeder, D.J. and Kappel, W.M., 2009, Water Resources and Natural Gas Production from the Marcellus Shale: U.S. Geological Survey, Fact Sheet 2009–3032, 6 p.

A big, modern drill rig like the H&P is designed for shale. It has less manual labor than the more primitive rigs from the old days, but more skilled jobs. The doghouse is still mounted to the rig floor but consists of a clean, climate-controlled facility that is bursting with electronics. Instead of a throttle and brake, the driller controls the rig from a computer screen with a joystick. Sensors on the rig collect reams of data on bottomhole temperature, weight on bit, rotation rate, rate of penetration, mud pressure, pore pressure, and a host of other parameters. The driller may have an electronics assistant to keep the information technology up and running. Hydraulic arms controlled by the driller are used to lift drill pipe and casing, and thread joints together while the roughnecks add pipe dope and then stand back and watch. The tool pusher visits the site less often because their office is connected to the drill rig computer via the internet, and they receive the same data as the driller in real time. There are still a few roughnecks on modern rigs and a mud logger collecting cuttings, but a new addition to the crew is another geologist performing "geosteering." This is to help keep the borehole on track for directional drilling of the laterals.

A Unit Corporation BOSS (Box On box Self-Stacking) modular drill rig deployed on the Niobrara Formation in eastern Colorado, USA is shown in figure 4. This rig is similar to the H&P in size and operations. Each drill pipe string in the stand next to the derrick consists of three joints with a combined height of 30 meters. The derrick itself is about 40 meters high. The trailer-like structure mounted to the side of the rig under the American flag is the doghouse from where the driller controls the operations. The scale of the rig can be appreciated by the size of the "normal" entrance door to the doghouse at the top of the stairs. Additional strings of drill pipe are laid out in the foreground. A second BOSS rig can be seen in the far background.

Oil and gas operations are rather sharply divided between "onshore" or land operations and "offshore" or ocean drilling. Although a lot of the production technology is the same, the approaches are quite different and there is not actually a lot of technology from one that can be transferred to the other. The exception to this is directional drilling.

Directional drilling was invented in the 1930s with the development of a flexible drill pipe called a "whipstock." This allowed the drill string to be rotated from the surface and go through downhole curves without shearing off. It never became very popular because steering the bit was difficult, and it would often wander off in random directions deep underground. Knowing the location of the bottom of the hole was also challenging, with little more than a primitive downhole gyroscope and compass, dead reckoning, and luck.

This changed in the 1990s as the major oil companies involved in deepwater offshore oil production decided that directional drilling technology would be useful. Moving the semisubmersible, tension-leg platforms that are required for very deep water is expensive, time-consuming, and risky when trying to drill several close targets in structures like salt domes. Directional drilling allows operators to install multiple wells into different nearby targets without having to move the platform. As such, the big oil companies put significant money into developing directional drilling and practical systems became available around the end of the last century.

Unlike older drill rigs that rotate the entire drill string from the surface to turn the bit, shale rigs like the H&P use the drill pipe as a non-rotating conduit for high-pressure drilling mud to be pumped downhole. The pressurized mud enters a bottomhole assembly that incorporates a hydraulic motor to turn the bit (figure 5), cutting the hole and allowing the bit to be steered. With only the bit rotating in the bottomhole assembly, the stationary drill pipe in the borehole is much more flexible and the hole can contain fairly tight curves. Advanced bottomhole assemblies incorporate thrust bearings that can change the angle of the bit to provide precise directional control.



Figure 4: A large, triple rig similar to the H&P Flex rig drilling into the Niobrara Formation in eastern Colorado, USA. Photo by Dan Soeder, 2016.



Figure 5: A pair of bottomhole assemblies for the drill rig shown in the previous figure. Each contains a hydraulic motor at the yellow "twist" to turn the bit and the only part of the assembly that rotates is the blue section. Photo by Dan Soeder, 2016.

Related improvements in downhole position measurement based on inertial navigation and real-time telemetry of data back to the surface now allow drill crews to perform geosteering to configure the borehole by accurately monitoring the downhole location of the drill bit. A specialized drill bit designed for shale has also improved drilling efficiency in these formations. Standard tricone rotary bits work by percussion and tend to be inefficient in soft rocks like shale. The polycrystalline diamond composite (PDC) drill bit has superior performance. PDC bits use raised cutter teeth and oriented jets that focus high-pressure drilling fluid onto the cutting surfaces to flush away the mud buildup that accumulates when drilling through shale (figure 6). Experienced shale drillers in North America can routinely drill 700 m of borehole in a day, and some drill as much as 1.5 km daily.



Figure 6: New polycrystalline diamond composite (PDC) bit in its plastic case on the left; used, standard tricone bit on the right. Note how jets on PDC bit are designed to wash mud off the cutting teeth. Coins for scale are 19 mm in diameter. Photos by Dan Soeder, 2016.

George P. Mitchell of Mitchell Energy in Dallas, Texas had been interested in shale gas for decades. His company had been deeply involved with the U.S. Department of Energy (DOE) shale gas

program in the 1970s-1980s that was set up in response to the OPEC oil embargo and the resulting U.S. "energy crisis." The DOE shale program was never very successful, having focused on vertical wells in shale with a single hydraulic fracture zone. We now know they weren't thinking big enough. After the DOE program ended, George Mitchell continued to investigate technology to produce shale gas. With the luxury of owning his own drilling company, he stubbornly refused to quit despite his brother and partners pleading with him to do so. Others in the oil and gas business thought Mitchell's obsession with shale was just an old man's eccentricity. Even his own employees considered the shale effort to be a waste of time[6].

Undeterred, George Mitchell applied the recently developed offshore directional drilling technology to drill long horizontal boreholes into shale that made much greater contact with the rock than vertical wells. The horizontal wells also allowed him to hydraulically fracture the rock in multiple stages at different locations along the length of the lateral, instead of the single stage fracks that were typical of vertical wells. Mitchell's methods began to achieve success in the Barnett Shale in the Fort Worth basin of Texas in the late 1990s, resulting in the first shale gas drilling boom in the United States in the Dallas-Fort Worth area. The idea spread as many other shale gas resources were developed in the U.S. and elsewhere over the following two decades. George P. Mitchell was honored by the Gas Technology Institute for his role in pioneering shale gas into an economic resource, and for creating the shale gas revolution. He passed away on July 26, 2013, at the age of 94.

The history of large triple rigs in the United States began in the 1980s when they were developed to drill deep, conventional boreholes on the Texas – Louisiana Gulf Coast. They began appearing on shale plays in the Appalachian basin and in the Rocky Mountains during the first decade of the 21st Century where they had not previously been seen. This was especially shocking in the Appalachian basin because although this region hosted the world's first oil well in 1859, most of the drilling over the years had been done by small operators with modest, truck-mounted rigs. Triple rigs are now a common sight in Ohio and Pennsylvania as companies pursue dry gas from the Marcellus Shale and gas and condensate from the Utica Shale. People who signed leases early on to allow shale gas wells to be drilled on their small farms were understandably surprised when a gigantic drill rig like the one shown in figure 7 arrived and set up shop in their pasture. Folks are a bit more savvy these days, and the drilling companies have also gotten better about explaining exactly what is involved.

These rigs are used because they are the only equipment capable of drilling the long laterals at depth, which appear to be growing ever longer. Many gas shales are quite deep, and although some formations may be reachable with smaller rigs, continuing a deep vertical borehole into a lateral that may need to extend several kilometers horizontally is beyond their capability. Triple rigs are robust enough to drill record-setting wells like the Outlaw C11 H, constructed in the Utica Shale in southeastern Ohio in 2017 by Eclipse Resources[7]. According to a company news release, the lateral in this well has a length of almost 6 km, with a total borehole length from the surface to the end of the lateral of about 8.5 km. Recently, Eclipse has supposedly drilled several even longer laterals. These extremely long wells are said to be very efficient, paying for the extra drilling costs with substantial

[6] Soeder, Daniel J., 2018, The successful development of gas and oil resources from shales in North America: *Journal of Petroleum Science and Engineering*, v. 163, p. 399-420.

[7] Soeder, Daniel J., 2021, Fracking and the Environment: Cham, Switzerland: Springer Nature Switzerland AG, 279 p.

returns of natural gas or liquid hydrocarbons. They are also beneficial to the environment because the longer laterals allow for greater well spacing on the surface.



Figure 7: Triple rig drilling the Marcellus Shale on a farm in southwest Pennsylvania. Photographed by Dan Soeder in 2011.

In the U.S., the nominal spacing for vertical wells in a conventional oil or gas field is one well per 40 acres (16.2 hectares). George Mitchell began spacing horizontal wells in the Barnett Shale 80 acres apart, but then quickly discovered that a spacing of 160 acres (64.75 hectares) was more efficient. This became more-or-less standard during the development of many of the subsequent shale gas resources, but it can vary based on formation permeability, fracture trends, regional structure, and other factors. However, the trend has been toward longer laterals with multiple directional wells per pad, and on some shale plays the pads are at a spacing of 640 acres, equivalent to one well pad per square mile (2.59 km^2). This has significantly reduced landscape impacts.

As shale gas development matured, a number of drilling rig manufacturers began building rigs specifically for shale. Rather than adapting conventional drilling equipment for use on gas shales as was done in the early days, it turned out to be more efficient to purposely design new drill rigs to meet the challenges of shale drilling. The H&P Flex rig is one of these. The specialized shale rigs began to appear in the U.S. about ten years ago at the height of the shale gas and tight oil boom. There were dozens of rigs on the Marcellus and Utica shales in the Appalachian basin, on the Bakken Formation in the Williston basin of North Dakota and Montana and Saskatchewan in Canada, on the Eagle Ford Shale along the Texas Gulf Coast, the Niobrara Formation in the Denver-Julesburg basin of Colorado, and the Woodford Shale in the Anadarko basin of Oklahoma, among others. Most of the boom-type activity at this writing has tapered off, although drilling on many of these plays is continuing at a less frantic pace. The only significant shale boom at present in the U.S. is the stacked gas and liquids shale play in the Permian basin of west Texas and eastern New Mexico.

The laterals for shale gas are not drilled in random directions. The engineers who design the layout of the wells are cognizant of regional stresses. Hydraulic fractures at depth break vertically in the direction of maximum horizontal compression. The engineers want the fractures to grow in a direction at right angles to the orientation of the lateral so the cracks will move as far as possible into the formation to create permeable flow paths. Thus, the laterals are drilled in the direction of minimum compressive stress, which is perpendicular to the maximum stress direction. For example, if the direction of maximum compressive stress is east-west, minimum stress is north-south. A number of laterals can be drilled to the south and an equal number to the north from both sides of the pad. Because of the directional drilling control of the boreholes, multiple wells (sometimes dozens) can be drilled on the same pad without interfering with one other.

A truck-mounted double rig could be easily moved around on the pad to drill additional wells, but with the modular triple rigs, drillers found it to be time-consuming and expensive to take the whole thing apart, move it 20 meters to the next wellhead location and set it back up again. Thus, the H&P rig and others have the ability to "walk" short distances on the pad, up to about 25 meters, to the next well location. This allows multiple wells to be drilled on a pad without dismantling the rig. An arrangement of hydraulic feet pick up, move a short distance and reset, and then the entire rig platform slides to the new position. The operation is slow and painstaking, but still much faster than taking the rig apart and putting it back together a short distance away. Like the H&P rig, the BOSS rig shown previously in figure 4 can also walk. These rigs have been used for a least a decade in the USA, and there is no record of one ever having a problem because of the ability to walk.

Like the BOSS rig, the H&P rig is designed to use the bottomhole assembly with a downhole hydraulic motor powered by pressurized drilling mud to turn the bit. This allows the drill string to remain stationary (not rotating) in the borehole so the driller can transition smoothly from the vertical top hole through the kick-off point and into the curve, creating a long lateral borehole (refer back to figure 3). Laterals in the Beetaloo basin can be expected to be at least 1 km long, and they will

probably go longer if the rock will allow it. Staged hydraulic fractures will be done at spacings defined by the rock; the Tamboran news release states that the stages will be spaced at intervals of about 50 meters in their first lateral. This is a bit intense compared to U.S. laterals, where the frack stage intervals tend to be about 150 meters in length. The U.S. spacing would result in about 6 or 7 stages in a 1,000-meter lateral versus 20 at Tamboran's spacing, but of course this is defined by the rock properties. The super-long Outlaw well in Ohio described earlier had about 40 frack stages at 150 meter spacing.

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Although most of the environmental concerns in the U.S. have been directed toward hydraulic fracturing, there have been some environmental issues related to drilling. The frack process involves much more equipment and supplies than the drilling operation and is more visible to the communities surrounding the well location as all this material is transported out to the drill site and set up. Nevertheless, the drilling process has also caused some groundwater contamination, such as when poorly lined mud pits allowed drilling mud to seep into the ground (figure 8).



Figure 8: Drilling mud seeping from an eroded embankment into a stream below a shale drilling operation in West Virginia, USA. Photo by Doug Mazer, used with permission.

The most significant impact from shale gas drilling occurred when groundwater in drinking water supply wells near drilling operations turned cloudy and became undrinkable. People frequently took jugs of gray, dingy water to local government meetings to complain about fracking. In other cases,

methane gas within the aquifer was mobilized to the point where some folks could set their kitchen faucets alight while running tap water. Spectacular photographs of flaming faucets made sensational stories in the news media, and for a time water taps set ablaze became the unwanted symbol of the fracking industry. Despite explanations that the fracks remained several km below the fresh groundwater, people associated methane in their plumbing with fracked natural gas. In at least one case, a number of water wells near a drilling operation had water fountaining out of the top of the wells several meters into the air.

With my background in both hydrology and petroleum, I was tasked with investigating these problems when I worked at DOE. I learned that the drillers would typically drill the tophole or the vertical part of the well using compressed air instead of drilling mud. The rigs turned the drill string from the surface using air to cool the bit and clean out the hole, and then they would switch over to a bottomhole assembly with a mud motor to drill the curve and the lateral. The air-drilled vertical holes could be constructed more quickly, cleanly, and cheaply than boreholes drilled using mud. The problem was that the compressed air, at some 600 psi (41 bars) was entering the aquifers. I enlisted the help of some colleagues at the New Jersey Institute of Technology to run computer simulations on what this pressure might do to groundwater[8]. They found that the compressed air expanded into the aquifer and displaced the groundwater, forcing it to surge away from the shale gas well, sometimes at a pretty good clip depending on the rock properties. The fast-moving water would pick up sediment and minerals in the pore system, causing the cloudiness and bad taste. Methane that occurred naturally from microbes living within the aquifer would be mobilized by the surge and turn up in kitchen faucets. And in the case with the fountains, the surge was strong enough to push the water right out of the wells.

I gave a talk at a petroleum engineering drilling conference where I explained that the air being used during the tophole drilling was causing many of the problems with shallow aquifers and the resulting bad publicity. Once the surface casing is set, the aquifers are protected behind a centimeter of steel, but of course while the actual drilling is going on the aquifer rocks are exposed and vulnerable. This was when the compressed air entered the formations and created all sorts of havoc. I suggested that the drillers stop using air and switch to mud instead for the entire length of the borehole. Drilling mud is mostly water and incompressible, so if it gets into the aquifer, it pressurizes the groundwater a bit, but as soon as a small amount of fluid moves into the formation the pressure drops off rapidly. The word got out and was passed around quickly. Water well contamination incidents dropped substantially after the drillers took my advice and switched from air to mud.

I found this out when I tried to set up a field experiment a few months later to measure the actual response of water in shallow aquifers in real time as a shale rig drilled through them with air. I talked to a dozen different drilling companies and all of them told me that they were no longer using compressed air and had switched over to mud. I said I was looking for just one air drilling rig so I could collect some data. The person on the other end of the phone replied, “We stopped drilling with air because YOU told us to.” So, it was both a success and a failure at the same time. It is important that the H&P rig use drilling mud instead of compressed air for the tophole drilling in the Beetaloo basin to avoid significantly affecting local aquifers.

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[8] Geng, X., Davatzes, N. C., Soeder, D.J., et al., 2014, Migration of high-pressure air during gas well drilling in the Appalachian Basin, *Journal of Environmental Engineering*, v. 140, no. 5, B4014002.

Another challenge of this investigation was that drilling companies typically avoided going to court over a threatened well water contamination lawsuit. They figured it was cheaper to simply pay off the plaintiffs to settle the dispute. The companies also usually required the payees to sign a non-disclosure agreement (NDA). People who had suffered incidents that affected their wells were prevented by the NDA from disclosing to investigators exactly what happened. Industry wasn't talking either and it was very difficult for us to piece together the story from bits of public evidence and observations.

To almost no one's surprise, the easy payoffs for contaminated water wells were open to abuse – all one had to do was complain and money would be received in return. Some landowners began telling shale drillers that they had caused poor water quality and methane gas problems in water supply wells when these had actually been problems in certain water wells for a long time. Because of the quick, almost no-questions-asked payoffs after a complaint, more than a few of these complainers made some easy money. The industry finally wised-up after a case in Parker County, Texas where the drilling company decided to investigate and found that the chemistry of the "stray gas" reported by the homeowner did not match the chemistry of the gas in the Barnett Shale, which he claimed was polluting his well. It did match the chemistry of gas in a sandstone formation directly beneath his aquifer. Suspicious drilling company attorneys turned up videos that the plaintiff had posted on social media showing him flaring off methane gas from his water well a good ten years before the shale well adjacent to his property was even drilled[9]. The investigators concluded that the gas in the Parker County well was coming from the formation beneath the aquifer, which had been penetrated by the water well when it was drilled a bit too deep. Since the government had ordered the Barnett well shut down during the investigation, the company lost money. They counter-sued the homeowner for fraud, who had to pay restitution and legal fees. So much for easy money. Gas drillers now routinely collect pre-drilling samples from all existing water supply wells within a few km radius of the well pad location for analysis to document what is and is not in the groundwater before the drilling starts.

Once they are set up and operating, these drill rigs run day and night, 24 hours a day and seven days a week until the well is completed. If they are drilling multiple wells on a pad, they could be there for months. They are noisy, emit black smoke from diesel generators, and are lit up at night like a casino. In fact, the easiest way to find active drilling in an area is to drive around at night and look for the illuminated derricks, which can be seen from miles away. Having one set up across the street from your home can be devastating, and more than a few people have taken long vacations to get away until the wells are completed and in production.

Humans can leave, but what about animals? A few studies have been done to investigate the possible disorientation of birds by the lights and the effects of noise on local animal populations. However, the impacts are largely unknown, and shale development in a new area like the Northern Territory may be detrimental to wildlife, especially night flyers like bats. This is something that very much requires investigation. The construction activity on the wells is relatively short-term, but it can be very disruptive to local wildlife. The noise, lights and constant activity will scare off most wildlife,

[9] Pope, P.G., 2012, Parker County study: presentation at Stray Gas Incidence and Response Forum: July 24-26, Cleveland, Ohio, in Veil, J., 2012. A White Paper Summarizing the Stray Gas Incidence & Response Forum, Ground Water Protection Council, 48 p.

and the animals may take months to return to the habitat after the rigs and equipment are gone. The well installation activity may drive territorial animals in particular into the territories of their neighbors, and there can be many years of disruption in mating patterns and other behavior until boundaries become re-established. The lights on the rigs at night can be disorienting to birds and also potentially to bats, resulting in mid-flight crashes into the brightly lit-up derrick. Formal studies of this are sparse, but it has been documented on a number of bird blog sites.

Impoundments on well pads for supplies of fracking water may provide what is known as an "attractive nuisance" that may draw waterfowl. As long as the pond is filled with just water, it is not harmful to the birds or other wildlife. However, with the stated intent of using evaporation ponds to dispose of flowback and produced water, the presence of toxic organic compounds and high TDS brines may pose a risk to waterfowl. The ponds may also attract other animals that come to drink. One problem experienced in Pennsylvania is that these ponds are attractive to human teenagers.

4. WATER SUPPLIES AND FRACKING

Hydraulic fracturing is a completion technique used to stimulate the production of hydrocarbons from a well. The slang term frack has been adopted by some environmental groups as an overall description of the entire shale gas production process, and the industry objects strenuously to the misuse of the word. Calling a bulldozer clearing a pad or a drill rig boring a hole "fracking" does nothing but convince industry that opponents do not understand how the industry operates and are not capable of carrying on an adult conversation.

The misappropriation of frack by environmentalists has resulted in industry changing the spelling. They now always refer to it as a "frac" without the "k" to separate themselves from environmentalists who are outside of the industry. I personally object to the "frac" usage because words in the English language with hard "k" sounds do not usually end in a "c." For example, back, hack, pack, etc. The "c" ending is used for French words like lac or cul-de-sac. This issue may seem trivial, but both sides of the fracking debate will immediately place someone in one camp or the other depending on how it is spelled. My book "Fracking and the Environment" drew a lot of ire online from industry people because I used the "k" spelling in the title, but as I explained in the book, it fits with other English "ack" words and avoids absurdities like "frac'ed" or "frac'ing." In my opinion, the whole issue is ridiculous, and arguing over this made-up slang word just provides one more excuse for people to talk past one another.

Hydraulic fracturing operations are expensive and logistically challenging. They are not performed by the drilling company but by a specialized oilfield services company that comes on site after the rig has departed. The idea for cracking open the rock to produce oil and gas was first patented in the U.S. in 1866. Colonel Edward Roberts, an officer in the Union army during the American Civil War noticed that the shock waves from artillery shells exploding in water bodies would crack rocks. He used a charge of gunpowder (later nitroglycerin) lowered into a water-filled well and detonated it with a sliding weight. This helped to improve production but was not always effective. High explosives expend their energy quickly, shattering the rock near the wellbore but not extending fractures very far into the formation.

Hydraulic fracturing was invented and patented in 1947 by Floyd Farris of Stanolind Oil Company operating in the Hugoton gas field of Kansas, USA. Rather than employing an abrupt shock wave, Farris discovered that a slow pressure rise on naphthalene liquid filling a well would fracture the rocks and maintaining that pressure would cause the crack to continue to grow into the formation. He was able to extend fractures more than 300 m from a wellbore. Farris also pioneered the emplacement of a granular material such as sand into the fracture to prop it open after the pressure was released. The Stanolind patents were purchased by Halliburton Oilfield Services in 1949, and they continued to develop the process into the modern water-based version. Halliburton fracked the first commercial oil and gas wells in the early 1950s and they remain the top supplier of hydraulic fracturing services[10].

The hydraulic fracturing operations on shale wells are complex and involve large amounts of materials and machinery. An individual frack on a shale well uses nearly 4 million liters of water,

[10] Montgomery, C. T. and Smith, M.B., 2010, Hydraulic fracturing: History of an enduring technology: *Journal of Petroleum Technology*, v. 62, no. 12, p. 26-32.

thousands of liters of chemical additives, and over a tonne of sand as proppant. Most shale wells receive multiple fracks. All the material must be transported to the well pad, along with machinery to blend the sand, chemicals and water, pump trucks to pressurize the fluid in the borehole to create the fracture, and an array of instrument trailers and trucks to monitor and control the operation. A hydraulic fracturing operation underway on the Marcellus Shale in Pennsylvania is shown in figure 9.



Figure 9: Hydraulic fracturing operation on a pair of Marcellus Shale wells near Waynesburg, Pennsylvania, USA in 2011. Photograph by Dan Soeder.

The frack operation shown in figure 9 is complicated and it may be challenging to discern the individual components by readers who are unfamiliar with it. (Also it was a rainy day and the site was a muddy mess.) On the right side of the picture is a crane dangling a string of production casing with packers between two massive wellheads. Because the drill rig had left the site, a crane was used to lower and retrieve materials from the wells. Behind the crane is a row of red pump trucks, one of which is pumping away as evidenced by the cloud of diesel exhaust above it. The array of pipes and hoses behind the wellheads are feeding materials into the "blender," which is the white tank on wheels behind the right wellhead. The upstream side of the blender is at low pressure to receive water, sand, and chemicals, whereas the downstream side feeding these materials into the frack is under high pressure. The chemical additives are in the gray tanks on the left side of the photo. The tank in the background with two men on top contains the sand used for proppant. The water is in a fairly large impoundment behind the photographer. I stood on the pond berm to get this picture because it was elevated slightly above the site. Most of the other vehicles on the pad are for instrumentation, monitoring, and control.

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What follows is a brief step-by-step description of the type of high volume hydraulic fracturing operation usually carried out on horizontal shale wells. A minimum well depth of at least 800 m is required to obtain enough downward compressive stress to force a hydraulic fracture to break vertically. A hydraulic fracture created at too shallow a depth will uplift the rock vertically and form a horizontal crack. This is known as "pancaking" in industry parlance and is very inefficient for production. Fracking in long laterals is done in stages of about 150 m each in the U.S., although this varies. The first stage begins at the farthest or "toe" end of the lateral and successive stages work backward toward the "heel" to where the well becomes vertical. Each stage receives a set of perforations followed by the hydraulic fracture treatment. It is then sealed off behind a packer while the next stage is treated. The packers are removed for production to allow the free flow of gas after all stages have been fracked. The fracking procedure may vary slightly from well to well, depending on the configuration of the borehole and the surrounding geology. The most common steps are described below:

Step 1. Prep and cleanout: The process starts by cleaning the perf holes using a 15 percent solution of hydrochloric acid (HCl). Perforating the casing with high explosives tends to force pieces of steel and pulverized cement into the formation, and these must be removed. While the acid is cleaning out the perforations, the hydraulic fracturing system undergoes pressure testing and all the equipment is calibrated.

Step 2. Fracture initiation: The well is filled with water containing a chemical additive called polyacrylamide, creating an extremely slippery liquid known as "slickwater" that reduces pressure losses due to friction. The frack fluid must be pumped long distances (often several kilometers) from the surface down to the fracture stage and can suffer downhole pressure losses as great as 50 percent without slickwater. The pump trucks gradually increase pressure on the fluid until it exceeds the formation strength and cracks open the rock. This is called the breakdown pressure and represents the initiation of the hydraulic fracture.

Step 3. Pumping the frack: Because water is virtually incompressible, as soon as the fractures are created and water begins flowing into them, more water must be added at the surface to maintain the pressure. The initial part of the fracture, called the pad, is made with slickwater only. Behind this, as the fracture opens up, sand is pumped in with the water to act as a proppant that will hold the fracture open after the pressure has been released. Fine-grained sand is pumped into the fracture initially, followed by coarser sand as the fracture system develops. Water pressure and pump rates are maintained until the hydraulic fractures extend outward to distances as great as 300 meters from the well, which can be tracked using an array of special microphones called "geophones" in a process known as microseismic monitoring. The fractures themselves do not have to be especially wide to create high-permeability flowpaths for gas in ultra-tight rocks like shale. Laboratory permeability measurements showed that barely-visible hairline cracks allowed significant gas movement in shale[11].

[11] Soeder, D. J., 1988, Porosity and permeability of eastern Devonian gas shale: *SPE Formation Evaluation*, v. 3, no. 1, p. 116-124, DOI 10.2118/15213-PA.

Step 4. Isolating the stage: When a hydraulic fracturing stage is finished, the pressure is released and a seal is set into the production tubing to close off the perforated and fractured zone from the rest of the well. In the past these seals were typically bridge plugs made of solid cement or a composite material that had to be drilled out to open up the well after completion. Newer designs use a donut-like, inflatable rubber cylinder called a packer that is equipped with a check valve to seal off the stage. The valve blocks the downhole direction to keep frack pressure in the stage undergoing treatment from entering the previously fracked stage. When the well begins production, fluid and gas flow is in the uphole direction, and the check valves open.

Step 5. Moving to the next stage: The perf gun is reloaded and lowered back into the well, and another set of perforations is shot into the next stage of production tubing. The hydraulic fracture treatment is repeated on this interval, which is then closed off with another bridge plug or packer. The process continues stage by stage until reaching the heel. Depending on the size of each stage, the number of stages per lateral, and the number of wells requiring stimulation on a single pad, the typical hydraulic fracturing job usually takes about two weeks to a month to complete for each well pad location.

Step 6. Flowback and production: Flowback consists of the frack fluids pumped downhole to break the rock, plus some water from the formation (called produced water) pushed back to the surface by the flowing gas. This water is separated from the gas by gravity in a vertical tank at the surface and must be dealt with responsibly. It starts out relatively fresh with just frack fluids but becomes increasingly salty over time. The flowback is returned relatively quickly but output of produced water from the formation can persist for years, although the volumes usually taper off with time.

The amount of water needed for hydraulic fracturing is often claimed to be "millions of gallons," which converts into even more "millions of liters" per frack. Although individual frack stages rarely consume this much water, they can use about 4 million liters each and multi-stage fracks on long laterals can easily consume many tens of millions of liters in total. Depending on the formation, the amount of frack water returned as flowback can vary. In the U.S., only a small percentage of the water injected into the Marcellus Shale returns to the surface as flowback, but on the Eagle Ford Shale in Texas, much more is returned. This matters, because returned flowback water can be re-used in the next frack to ease demands on water resources, but water that remains in the formation downhole is removed from the water cycle and essentially lost forever. No one is really sure, by the way, about the fate of this "lost" water. It possibly imbibes into the pores and small fractures of the formation, or it may simply remain in the bottom of the hydraulic fractures. Given the ultra-low permeability of shale, I suspect the latter. The USGS has been attempting to assess the amount of water consumed by unconventional oil and gas development nationwide using water budget models, but the issue is complicated, data from operators are difficult to obtain, and there are many unanswered questions and loose ends[12].

Dealing with flowback and produced water can be challenging. Some operators filter out suspended solids and recycle the recovered water into another frack to reduce the waste volume and minimize the costs of disposal. This requires a degree of logistics to be effective and is only economical on certain shale plays where disposal costs are high and active development can readily use the water,

[12] Carter, J.M., Macek-Rowland, K.M., Thamke, J.N., et al., 2016, Estimating National Water Use Associated with Unconventional Oil and Gas Development: USGS Fact Sheet 2016-3032, 6 p.

such as the Marcellus. On the Bakken Shale in North Dakota where there is easy access to the Missouri River for supplies and plenty of disposal options, the water is used only once. The most common method for the disposal of produced water in the U.S. is by injection down permitted boreholes called Underground Injection Control (UIC) wells. However, overly-enthusiastic water disposal can increase the pore pressure along pre-existing deep faults, causing them to "unlock" and create earthquakes. These triggered earthquakes are known as induced seismicity.

There have been a few cases of induced seismicity in the U.S. associated with the disposal of produced water from shale in Ohio, and it has been a significant problem in Oklahoma, not previously noted as a hotbed for earthquakes. Although the Oklahoma quakes were blamed on shale development, the actual cause was enhanced oil recovery (EOR) operations in the Anadarko basin driven by sky high oil prices in 2014. Water injected down wells along the perimeter of an existing old oilfield can push additional oil towards central wells where it is recovered along with a lot of salty oilfield brine. The brine must be disposed of down UIC wells. The EOR activity generated far more wastewater than fracking, and excessive water volumes injected during the oil price boom triggered the Oklahoma earthquakes. When oil prices dropped, the recovery activity was discontinued and the seismicity stopped.

Induced seismicity has occurred during hydraulic fracturing operations but it is rare[13]. The best known example is the Bowland Shale in the United Kingdom, where multiple earthquakes in 2011 were linked to hydraulic fracturing operations near the town of Blackpool. The Bowland Shale is actually an organic-rich, shaly limestone, not a true shale and the limestone component may have given the formation significantly higher rock strength compared to clay-rich or even silica-rich shale. The greater rock strength in this formation would have allowed more stress to build up across a fault, and when frack fluids increased the pore pressure inside this fault it slipped, causing the earthquake. Most true shales are very weak rocks, composed of basically hardened mud. If stresses build up along a fault in shale, the rock is likely to break before the stress gets very high and relieve it. Disposal formations, in contrast, are usually much stronger sandstones or limestones that can accumulate stress and when triggered release it as more significant earthquakes.

The Bowland Shale has made the British Geological Survey the world's foremost authority on fracking-induced seismicity, albeit reluctantly. They have identified two types of induced seismic events. "Fracked" events are caused by the brittle failure of the rock as fracking creates new fractures. These quakes are usually quite small and often referred to as microseismic events. "Triggered" events occur when fluid raises the pore pressure and causes pre-existing faults to fail. The size of triggered events depends on the amount of stored-up stress present in the rocks.

The Beetaloo is a small rift basin that may have enough residual stress for earthquakes to be triggered by fracking. It will depend on the existing stress fields and the rock strength of the Velkerri Shale that is the production target. Tamboran Resources has described the Velkerri as similar in character to the Marcellus. If true, induced seismicity during fracking will likely not be a problem. The Marcellus is a fragile, crumbly shale for the most part without a lot of rock strength. It can't usually build up enough stress for earthquakes to be triggered by a frack.

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[13] Clarke, H., Eisner, L., Styles, P., et al., 2014, Felt seismicity associated with shale gas hydraulic fracturing: The first documented example in Europe: *Geophysical Research Letters*, v. 41, no. 23, p. 8308-8314.

The stated intention of Tamboran Resources in the Beetaloo basin is to dispose of the flowback and produced water by evaporation in the semi-arid environment of the Northern Territory. This alleviates concerns about induced seismicity from wastewater disposal wells. However, evaporative disposal has its own problems because of what is in the water and what gets left behind when it evaporates.

Flowback and produced water from shale gas wells usually contains a mix of chemicals and total dissolved solids (TDS). The flowback starts out as relatively fresh and increases in salinity over time[14]. This suggests that the frack fluid has grown salty downhole by reaching osmotic equilibrium with very saline connate water trapped in the shale pores. The TDS in produced water can be six to ten times saltier than seawater. The origin of these high TDS brines is not well understood but they appear to be a remnant mobile water phase deposited with the shale. In addition to NaCl, MgCl, CaCl and other common salts, the TDS in produced waters may include a variety of dissolved toxic metals such as barium, bismuth, chromium, cobalt, copper, nickel, and others. It may also include radionuclides as both uranium and radium are associated with organic-rich black shales. Some toxic compounds may be created downhole as additives in the frack fluid react with the rock and create new chemicals, which will return to the surface with the frack water[15]. Essentially all of the chemicals added to the frack fluid when it was pumped downhole will return in the flowback, along with additional salts and dissolved solids from the formation in the produced water. The concentrations of these compounds will increase as the water evaporates off.

There are a variety of different chemicals used in hydraulic fracturing, and these vary with the geologic formation being fracked. Indeed, the original frack fluid recipe developed by George Mitchell for the Barnett Shale in Texas did not work very well on the Marcellus Shale in Pennsylvania. It took Range Resources, the developer of the Marcellus, several years and numerous experiments with various formulations to come up with the combination of frack chemicals that worked efficiently in the Marcellus. It will likely take Tamboran Resources some time to figure out what works best in the Velkerri Shale.

Some standard chemicals can be expected. These include polyacrylamide to make friction-reducing slickwater, guar gum to thicken the fluid to carry the proppant, hydrochloric acid for cleanup, ethylene glycol for corrosion resistance, and a biocide to control downhole bacteria.

To penetrate shale, the surface tension of the water is reduced by adding polyacrylamide. This creates slickwater, which is so slippery that police forces around the world use it for riot control. Polyacrylamide itself is not particularly toxic, but as it naturally degrades one of the intermediate byproducts is acrylamide, a reproductive toxin and carcinogen[16].

Another standard chemical used in fracking is a biocide because the raw, untreated water injected into the ground will introduce microbes to the shale. Some of these could be “sulfate reducing” bacteria

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[14] Hayes, T., 2009, Sampling and analysis of water streams associated with the development of Marcellus Shale gas: Gas Technology Institute, Chicago; final report for Marcellus Shale Coalition, 49 p.

[15] Orem, W. H., Tatu, C. A., Varonka, M.S., et al., 2014, Organic substances in produced and formation water from unconventional natural gas extraction in coal and shale, *International Journal of Coal Geology*, v. 126, p. 20–31.

[16] Exon, J.H., 2006, A review of the toxicology of acrylamide: *Journal of Toxicology and Environmental Health*; Part B Critical Reviews, v. 9, no. 5, p. 397-412.

that will survive at depth and convert natural sulfate minerals in the shale like gypsum into hydrogen sulfide gas. Hydrogen sulfide is corrosive and toxic (actually deadly) and if it is generated downhole and mixes with the natural gas, the produced gas is called "sour." Sour gas must be treated to remove the hydrogen sulfide at added expense and it is cheaper to prevent the problem in the first place. The biocides are effective at killing bacteria, but they will also kill other life forms if there is a spill or leak on the pad. Glutaraldehyde is the most common biocide used. There was a famous picture on the internet a few years back of dead cattle in a field next to a fracking operation in the U.S. state of Louisiana where a tank of glutaraldehyde had leaked into the pasture and the cows lapped it up, with fatal results.

Hydraulic fracturing in shale requires less proppant sand than other kinds of fracks, but the number and volume of staged fracks in a long shale lateral still end up using a lot of proppant. The Jordan Sandstone in Wisconsin is one of the few formations in the U.S. that consists of evenly sized, well-rounded quartz grains with a high compressive strength that works well as a proppant. It has been used on almost all U.S. shale fracks. The Wisconsin state geological survey raised concerns that the extensive mining of this sand is causing significant damage to landscapes[17]. Manufactured ceramic proppants are available as substitutes, but their cost is usually significantly higher than natural sand. If Tamboran Resources cannot find a local source of frack sand in Australia, they will be forced to either import it or use the manufactured ceramic proppant. Neither of these options are as favorable for the economics.

The issue of water availability is a concern in a semi-arid scrubland like the Beetaloo basin, which has limited water supplies. The good news is that frack water does not need to be of drinking water quality, and degraded water can be used. Some of the major oil companies like Shell have even successfully fracked with seawater. As long as the TDS levels aren't so high that the performance of the chemical additives is compromised, just about any water source can and has been used, including treated wastewater effluent and undrinkable, brackish groundwater.

The U.S. government ran a multiagency investigation from 2012 to 2017 to assess the impacts of unconventional oil and gas development on the environment. I represented DOE on this group, which also included the USGS and the U.S. Environmental Protection Agency (USEPA). We found that water withdrawals for use on a basin-wide shale play are comparable to the water used by a medium-sized city like Darwin[18]. The difference is that a city returns most of its water back to the watershed as runoff or wastewater effluent, while fracking loses half to two thirds of the water downhole, where it remains forever. Such consumptive use of water is a concern because it can affect a water supply and may be detrimental to ecosystems. However, compared to water use in larger cities, the amounts required for fracking are relatively small.

[17] Parsen, M. and Zambito, J., 2014, Frac sand in Wisconsin: Fact Sheet 05, Wisconsin Geological and Natural History Survey, Madison, WI, 2p. (http://wgnhs.uwex.edu/pubs/fs05/)

[18] USDOE, 2015, Report on the Multiagency Collaboration on Unconventional Oil and Gas Research, USDOE Office of Fossil Energy, Report to Congress on behalf of the Multiagency Collaboration, December 2015, 24 p.

5. AIR, WATER, AND LANDSCAPE IMPACTS

Potential air quality impacts from fracking and other phases of unconventional oil and gas development have been investigated in U.S. production areas such as northeastern Pennsylvania, eastern Colorado and the Denver region, and the Dallas-Fort Worth area in Texas[19]. The air pollution associated with fracking and other oil and gas operations falls into three main categories: 1) particulate matter, 2) organic gases, and 3) nitrogen oxides[20].

Particulate matter or PM consists of dust and smoke from activities like site preparation and drilling activities, material transport on and off the pad, and proppant handling and use. Sources of PM include diesel and other engine exhaust, tire, brake and road dust, and silica dust from proppant sand[21]. It may also include dust from precipitates in dried-out evaporation ponds. Organic gases include VOCs like benzene, toluene, ethylbenzene and xylenes (known collectively as BTEX) and other light hydrocarbons like butane and ethane. Sources include engine exhaust, well completions, vented tanks, fluid transfer operations, storage and transport of drilling waste, flaring, equipment leaks, pneumatic controllers, and valves[22]. Nitrogen oxides or NOx are a byproduct of high-temperature combustion and are produced in engine exhaust during site preparation, material transport, drilling and fracking, and gas compressors[23].

Organic gases including light hydrocarbons such as methane, ethane, propane, and butane are released into the air when flowback is returned to the surface and placed in open pits or vented tanks[24]. This is done when the volumes are too great for the gas-water separators to handle, and before the gas transmission pipeline has been run to the well. They don't have anywhere to store the gas or sell the gas, so it is vented. This can be a significant source of air pollution. Flowback should be captured in closed tanks, not open pits, to keep the gases and VOCs out of the air. Methane is a powerful greenhouse gas. Complex organic molecules in VOCs, especially aldehydes, will react with sunlight and moisture to form brown hazes or smog. These sunlight-driven reactions in the atmosphere create ozone, one of the most harmful pollutants in air. It can cause human health effects, harm birds and mammals, damage vegetation, and crack rubber and polymer materials. An

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[19] HEI (Health Effects Institute), 2019, Human Exposure to Unconventional Oil and Gas Development: A Literature Survey for Research Planning: Special Report 2 (Draft for Public Comment): Boston, HEI-Energy Research Committee, 108 p. (www.hei-energy.org)

[20] Allen, D.T., 2016, Emissions from oil and gas operations in the United States and their air quality implications: *Journal of the Air & Waste Management Association*, v. 66, p. 549–575; doi:10.1080/10962247.2016.1171263

[21] Moore C.W., Zielinska B., Pétron G., et al., 2014, Air impacts of increased natural gas acquisition, processing, and use: a critical review: *Environmental Science & Technology,* v. 48, p. 8349–8359, doi:10.1021/es4053472.

[22] Luck, B., Zimmerle, D., Vaughn, T., et al., 2019, Multiday measurements of pneumatic controller emissions reveal the frequency of abnormal emissions behavior at natural gas gathering stations: *Environmental Science & Technology Letters*, v.6, p. 348–352; doi:10.1021/acs.estlett.9b00158

[23] Zielinska, B., Campbell, D., and Samburova, V., 2014, Impact of emissions from natural gas production facilities on ambient air quality in the Barnett Shale area: a pilot study: *Journal of the Air & Waste Management Association*, v. 64, p. 1369–83; doi:10.1080/10962247.2014.954735

[24] Pekney, N., Reeder, M., and Mundia-Howe, M., 2018, Air Quality Measurements at the Marcellus Shale Energy and Environment Laboratory Site: *EM The Magazine for Environmental Managers*, August 2018, Air & Waste Management Association, 5 p.

investigation of fugitive methane emissions once the well is producing found that the compressors were the greatest source of methane leaks. Well operators lose a saleable product when methane leaks to the atmosphere, along with contributing to climate change.

On a positive note, dust generated from equipment traffic on unpaved roads near well pads does not appear to substantially affect birds or invertebrates, even though the PM traveled nearly 200 m into adjacent fields[25]. Neither bird abundance or behavior, nor invertebrate abundance or community composition appeared to be affected by PM. The study was carried out on agricultural landscapes like crop fields, and wildlife in a previously undisturbed habitat may respond differently.

Another source of dust is a concern. Tamboran's plan to dispose of flowback and produced water by allowing it to evaporate in large impoundments will concentrate dissolved solids in these ponds. Some of the compounds likely to precipitate out of the evaporating water include a variety of metallic salts, some of which are toxic or possibly radioactive, and dissolved organics like the biocide, which may be toxic as well. If these materials are picked up from a dry pond bottom and carried off as dust in the wind, they can pose an environmental and health hazard. An example is the Aral Sea between Kazakhstan and Uzbekistan, which began shrinking in the 1960s after the rivers that supplied it were diverted for cotton irrigation. It had largely dried up by 2014. The toxic dust accumulated on the dried sea bottom from precipitated salts and chemicals caused serious health effects in surrounding populations exposed through windborne transport[26].

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In terms of water impacts, the U.S. government multiagency study mentioned previously identified at least four potential sources of contaminants associated with the development of shale gas that may present water quality risks to groundwater and surface water. These are, in approximate chronological order of use:

1) The various drilling fluids such as mud, lubricants, cement compounds, and other substances employed when constructing the borehole.

2) The concentrated chemicals, conditioners, and performance enhancers stored on the well pad in large volumes and blended into the frack fluid[27].

3) The fluids produced out of the well after fracking, including flowback of the original frack fluid and water produced from the formation itself. Produced water contains high TDS, hydrocarbons, dissolved solids like barium extracted from the rock[28] and new chemicals formed by downhole reactions between the frack fluid additives and the formation (refer back to Orem et al., reference 15).

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[25] Spiess, J., McGranahan, D.A., Whippo, C., et al., 2020, Bird and invertebrate communities appear unaffected by fracking traffic along rural roads despite dust emissions: *Ambio,* v. 49, no. 2, p. 605–615.

[26] O'Hara, S., Wiggs, G., Mamedov, B., et al., 2000, Exposure to airborne dust contaminated with pesticide in the Aral Sea region: *The Lancet*, v. 355 (9204), p. 627–628. doi:10.1016/S0140-6736(99)04753-4.

[27] Soeder, D. J., Sharma, S., Pekney, N., et al., 2014, An approach for assessing engineering risk from shale gas wells in the United States, *International Journal of Coal Geology*, v. 126, p. 4-19

[28] Renock, D., J.D. Landis, and M. Sharma. 2016. Reductive weathering of black shale and release of barium during hydraulic fracturing. *Applied Geochemistry*, v. 65, p. 73-86.

4) Black shale drill cuttings, drilling mud residue, contaminated soil, and other solids left behind on the drill pad that may oxidize, weather and leach inorganic and organic chemicals, heavy metals, radionuclides, and other potentially toxic substances into shallow groundwater[29].

One of my geochemist friends has described the organic-rich black shales that are targets for gas production as the "wastebaskets of the sea." In addition to organic matter, these shales attract radionuclides like uranium and radium, various heavy metals like chromium and barium, sulfide compounds including iron sulfide (pyrite) and hydrogen sulfide, and a variety of organic chemicals. The drill cuttings recovered from shale wells are considered by most environmental agencies to be a "natural material" that requires no special handling. In my discussions with state environmental officials, they have pointed out that black shale outcrops occur naturally in many places along streams, yet the rock does not measurably contribute to water contamination. That may well be true, but any toxic metals, mobile radionuclides, and harmful organics will have been removed from natural outcrops over geologic time by erosion and weathering. In a pile of fresh shale drill cuttings, these materials are being exposed to oxygen for the first time in millions of years and leach into groundwater. There is also a potential for the finely divided drill cuttings to release VOCs into the air for a short period of time. Even on many natural outcrops of black shale, a sample cracked open with a rock hammer will release the scent of hydrocarbons.

Other countries handle shale cuttings differently than the U.S. A study in the European Union focused on the abundance of metals and trace elements in shale drill cuttings that could be mobilized into water. Analyses confirmed that some constituents of the shale cuttings become mobile with changes in pH. Increased alkalinity of water leaching through the cuttings released components such as Ca, Rb, Mo, and Sr. The levels of dissolved organic carbon in the leachates remained low[30]. In China, investigators are assessing treatment and disposal methods for dealing with shale cuttings, instead of just leaving them on the well pad as is done in the U.S. The treatment methods for shale cuttings include restriction, separation, and degradation, while the disposal methods were divided into landfill, land farming, and resource recovery[31]. Another Chinese study found that if the material is used in a highway road base, the human carcinogenic risk is small[32].

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In the United States, the construction of roads, drill pads, large water impoundments and other infrastructure for shale gas development has caused significant impacts to the landscape. Some of the

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[29] Phan, T.T., Capo, R.C., Stewart, B.W., et al., 2015, Trace metal distribution and mobility in drill cuttings and produced waters from Marcellus Shale gas extraction: Uranium, arsenic, barium, *Applied Geochemistry*, v. 60, p. 89-103.

[30] Piszcz, K., Łuczak, J., and Hupka, J., 2014, Mobility of shale drill cuttings constituents: *Physicochemical Problems of Mineral Processing*, v. 50, p. 795-810. 10.5277/ppmp140230.

[31] Deng, Y., Yin, H., Chen, Z. et al., 2022, Research Progress and Prospects on the Treating and Disposal for Waste Oil-Based Drilling Cuttings from Shale Gas Wells: *Geofluids*, v. 2022, Article ID 8208912, 15 p. https://doi.org/10.1155/2022/8208912

[32] Wang, C-Q, Chen, S., Huang, D-M et al., 2023, Human carcinogenic risk analysis and utilization of shale gas water-based drilling cuttings in road materials: *Environ Sci Pollut Res Int.*, v. 30, no. 5, p. 12741–12768.

shale plays like the Haynesville Shale in Louisiana and the Eagle Ford Shale in Texas had some conventional oil and gas infrastructure already in place, but many others did not.

Locations in northern Arkansas and southwestern Pennsylvania, respectively the sites of the Fayetteville and Marcellus shale plays, were rural and undeveloped, with few roads. The roads that did exist in these areas had not been designed for the transit of large, heavy equipment. Some locations were mountainous, with steep, narrow, winding roads that could not accommodate either the width or the turning radius of the giant triple drill rig components and other large equipment that needed to get to a drill pad. Thus, the first action often taken by industry when moving onto a new shale play was to bring in road graders and bulldozers to construct, widen, and straighten roads so equipment and materials could get in and out. Local governments often approved of this because after the drillers were gone, they ended up with improved roads at no cost. In some of the more forward-thinking counties in Pennsylvania, local highway departments worked with industry representatives to plan routes to well sites along roads that needed improvement anyway, with the promise that industry would repair and re-pave the road after wells were completed and heavy equipment was moved off-site.

The land area needed for a well pad is usually 5 acres (2 hectares) in the United States, and pads in the Beetaloo basin can be expected to be similar in size. This is to accommodate the large amount of equipment and supplies needed for hydraulic fracturing, not necessarily for the drill rig. Land disturbance area must also consider access roads, haul roads, and rights of way for pipelines and power lines. Pads designed for shale wells and fracking are typically constructed by clearing topsoil from approximately 2 hectares of land, laying down a heavy, impervious "geomembrane" to prevent any leaks or spills from infiltrating into the ground, and then covering the geomembrane with a layer of gravel nearly a foot (30 cm) thick.

Once about ten percent of the surface area in a watershed becomes impervious, storm water runoff events intensify and flash flooding is more likely[33]. A runoff modeling study at the DOE National Energy Technology Laboratory (NETL) assumed that a single well pad and associated access roads add about 3.25 hectares (8 acres) of impervious surface area to a watershed. The model outputs showed that impacts to a stream varied with catchment area and land use type. The least impaired land use type is forest, and the threshold for stream impact from a single well pad in a forested watershed occurs when the catchment area is 5 square km (2 square miles) or less. Catchment area threshold for stream impacts on other land use types that already have some degree of hydrologic impairment were 6.5 square km (2.5 square miles) on agricultural land, and 13 square km (5 square miles) on urbanized land[34]. The NETL assessment was done using only numerical models. Some actual on-the-ground measurements at drill sites in the Beetaloo basin would help provide rigorous data on the potential impacts of the well pads on small watersheds.

Another ecological concern related to shale development is known as "ecological succession," which refers to how an ecosystem rebuilds after an area has been cleared by fire, bulldozers, or other means. Primary succession occurs on new habitat that has never before been colonized, like a freshly

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[33] Barnes, K.B., Morgan III, J.M, and Roberge, M.C., 2002, Impervious surfaces and the quality of natural and built environments: Department of Geography and Environmental Planning, Towson Univ, Baltimore, MD 21252-0001, 28 p.

[34] Soeder, Daniel J., 2017, Unconventional: The Development of Natural Gas from the Marcellus Shale: GSA Special Paper 527, Boulder, CO: Geological Society of America Books, 143 p.

quarried rock face or sand dunes. Secondary succession refers to the process of ecosystem rebuilding in previously occupied habitat that has been disturbed or damaged, for example by clearcutting timber or by a forest fire. Any ecosystem attempting to re-colonize the constructed, unoccupied surface area of a well pad would essentially be undergoing a primary succession.

It is unclear how drill pads, roads, and pipeline access rights-of-way will affect succession. If left alone, a drill pad will become overgrown with grass, brush, and finally trees over a period of months to years. However, if the production site remains active, the ecology will not re-establish. The need for continuous, periodic visits to the pad for maintenance and other activities will require that at least some of the cleared area be kept accessible although the initial pad can be reduced to just those areas needed for production and maintenance activities like wellheads, produced water tanks, compressor, and metering line. In this case, most of the pad can be allowed to return to a climax ecology. The techniques applied to the management of these large, cleared well pad areas over time can have an impact on the local ecology.

Long-term degradation of an ecosystem may also result from the fragmentation of habitat crisscrossed by roads and pipelines. Fragmentation is a process where large expanses of habitat are transformed into multiple, smaller patches that are isolated from each other by barriers composed of habitats much different than the original[35]. For example, excavating a wide road through a scrubland will separate two previously joined expanses of habitat with a line of packed dirt that is definitely not scrubland habitat. Some plants and animals in the ecosystem can cross this boundary easily, but it may present an insurmountable barrier to others. Different species are affected in different ways, but because biodiversity relies on the complex interactions of various species within an ecological network, the effects of habitat fragmentation can extend well beyond just the species that are unable to cross the boundary and degrade the operation of an entire ecosystem. Fragmentation can lead to species dispersal, colonization, or even extinction.

The Beetaloo basin is largely undeveloped and will require roads to access the well sites and pipelines to transmit the gas to market. The only economical way to move natural gas is through a pipeline. Pipeline routes have been contentious in the U.S. and may also be an issue in Australia. Roads can fragment habitats. Some consideration should be given to the local ecology when laying out the routes for roads and pipelines.

Many of the activities related to oil and gas production these days are done with smart phone apps. If the Beetaloo basin sees shale gas development, the mobile phone coverage will significantly improve.

[35] Hagen, M., Kissling, W.D., Rasmussen, C., et al., 2012, Biodiversity, Species Interactions and Ecological Networks in a Fragmented World: *Advances in Ecological Research*, v. 46, p. 89-210.

6. RISK ASSESSMENT

There were very few studies of the potential environmental impacts of shale gas development in the United States until about ten years ago. Over the past decade, the floodgates have opened and the scientific literature is now overflowing with papers and articles, making it difficult to sort out relevant studies. The environmental effects turned out to be "less bad" than most of the researchers expected when they got started. Much of the fear of fracking was amplified by the news media, who tended to transform a single, isolated incident into death and destruction for everyone.

In terms of an actual risk assessment, a two-state comparison of environmental incidents associated with gas wells in Ohio and Texas found that gas wells have a rate of "reportable incidents" for environmental violations on the order of 0.5% to 0.1% or less of the total number of wells drilled[36]. This translates to one well out of 200 to one well out of 1,000 with reported problems and includes both unfracked and fracked wells. The majority of these "reportable" incidents were minor, such as incorrect signage or small spills. The major incidents that did occur were primarily related to the contamination of groundwater or surface water bodies from leaks or spills of chemicals on the surface. This had more to do with the competence of the operator rather than the type of well. There was no statistically significant difference in the incident rate between fracked and unfracked wells. The occurrence rate of incidents also had a lot to do with the frequency of state inspections. Texas had an overall lower incident rate than Ohio because state authorities inspected well sites more often.

A separate study found that wellbore integrity problems were more likely in fracked wells than unfracked but did not explain why[37]. Wellbore integrity means the failure of the steel casing that isolates the well from the surrounding rock and/or the failure of the cement that secures the casing and seals it in place. It doesn't necessarily mean that the well is leaking hydrocarbons into the air or groundwater, but the potential is there. My informed opinion is that the multiple fracks that are carried out in shale wells repeatedly stress the entire casing string (since fracks are pressurized from the surface) and lead to cracking of the brittle wellbore cement. Unfracked wells do not have this stress, and even fracked vertical wells only experience it once, not dozens of times like shale wells. The problem could be solved by leaving an air gap for expansion in the annulus between the production tubing and the intermediate casing, or by developing a spongy cement perhaps made out of recycled plastic that would flex instead of crack with the pressure.

One of the major challenges facing researchers who wish to better quantify the environmental impacts of shale gas development is the lack of cooperation from the oil and gas industry. Much of what has been learned to date has come from state records of environmental incidents and public well permitting reports. The United States government has no authority to compel industry to cooperate on such a study, and neither do the states. Given the amount of false information on the subject, one would think the industry would be eager to cooperate with researchers and set the record straight. However, that has not happened. The culture of the oil and gas industry is to respond to incidents

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[36] Kell, S., 2011, State oil and gas agency groundwater investigations and their role in advancing regulatory reforms: a two-state review, Ohio and Texas: report prepared for the Groundwater Protection Research and Education Foundation of the Ground Water Protection Council, 165 p.

[37] Ingraffea, A. R., Wells, M. T., Santora, R. L., et al., 2014. Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012. *Proceedings of the National Academy of Sciences* v. 11, p. 10955-1096.

when they arise, but not to go looking for problems. They consider research on environmental impacts to be looking for problems.

The bulk of the environmental research has found that the main risks to surface water and groundwater quality are gas migration, contaminant transport through induced and natural fractures, wastewater discharge, and accidental spills[38]. Other authors have identified similar risks, phrased slightly differently as stray gas in shallow aquifers, water contamination from spills or leaks of chemicals and shale gas wastewater, and accumulation of toxic and radioactive elements in soil or sediments.[39] [40]

The consensus view of a large group of North American hydrologists is that the most significant contamination risks from shale gas development are stray gas migration in aquifers, and the potential for contamination of both groundwater and surface water from the chemical additives used for drilling, completion, and hydraulic fracturing. The flowback and produced water from the wells also contain these chemicals, along with other compounds from the geologic formation, including high levels of TDS, dissolved metals, radionuclides, and organics. Another potential risk is leachate from solid materials like black shale drill cuttings left on the surface. Chemical contamination of groundwater occurs by infiltration and percolation from above, rather than migration upward from below for a host of reasons, including gravity and basic physics. This places surface water bodies like streams and lakes at risk, and if the chemicals infiltrate into the ground and reach the water table, groundwater can be at risk also.

Stray gas can be mobilized from naturally-occurring biogenic methane in aquifers if a surge of groundwater pressurized from air drilling transports the methane to supply wells. It can also come from the gas well itself if there are wellbore integrity problems due to split casing or cracked cement that allow gas to seep into shallow aquifers. Wells that have been pressure cycled multiple times from staged fracks are at greater risk of wellbore integrity failures.

There are numerous other environmental risks in an area undergoing shale gas development. These impacts can be especially notable in locations that are pristine and are just beginning to undergo gas drilling. Obvious risks like a large chemical spill will be noticed immediately and remediated. However, some of the more subtle risks to the environment, ecology, and habitat like the introduction of invasive species may take an extended period of time before they become visible.

As part of the U.S. government multi-agency assessment mentioned previously, we assembled a table of parameters to monitor for assessing environmental risks during shale gas development in a new area. These can also be applied to locations with a history of shale gas and other industry, but it is hard to determine how a drilling operation might have affected the local ecology when things have

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[38] Vidic, R.D., Brantley, S.L., Vandenbossche, J.M., et al., 2013, Impact of shale gas development on regional water quality: *Science*, v. 340. p. 826 (1235009)

[39] Vengosh, A., Jackson, R.B., Warner, N., et al., 2014, A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States: *Environmental Science & Technology*, v. 48, p. 8334−8348

[40] Lefebvre R., 2016, Mechanisms leading to potential impacts of shale gas development on groundwater quality: *Wiley Interdisciplinary Reviews: Water*, v. 4, no. 1, e1188, 15 p.; doi:10.1002/wat2.1188.

been disturbed for a hundred years or more ever since the railroad came through. The Beetaloo basin appears to have few legacy contaminants or environmental damages, and it may be the ideal setting for a detailed monitoring program to understand the true environmental impacts of shale gas drilling, hydraulic fracturing, and subsequent gas production. The table that follows is a "wish list" from a multi-disciplinary group of U.S. government scientists concerning the parameters that should be monitored around a shale gas development operation given both sufficient funding and industry cooperation.

Environmental Monitoring Before, During, and After Shale Gas Development

Category	**Parameters to Monitor**	**before**	**during**	**after**
Air Quality	Methane, CO2, dust, fumes, ozone	X	X	X
Drilling	Impacts of noise and lights on wildlife		X	
Drilling	Wildlife use of drilling ponds as a water source		X	X
Drilling	Collect fluid and gas samples during drilling		X	
Drilling	Microseismic monitoring of hydraulic fractures		X	
Drilling	Wellbore integrity assessment (cement and casing)		X	X
Ecology	Assessment of land and aquatic species assemblage	X		X
Ecology	Invasive species assessment	X		X
Ecology	Rare, threatened or endangered (RTE) species	X		X
Habitat	Effects of cleared pad on habitat/edge effects	X	X	X
Habitat	Resettlement of area afterward; succession			X
Landscapes	Monitor sediment, erosion and topography changes	X	X	X
Site Characterization	Land use, geology, topography, hydrogeologic setting, etc. to establish baselines	X		
Social	Property values, land access, timber, farming, etc.	X		X
Soil	Road/pad impacts on soil compaction, infiltration	X		X
Water	Establish surface water flow monitoring network	X	X	X
Water	Establish groundwater monitoring network: existing/new wells	X	X	X
Water	Establish water quality monitoring sites	X	X	X

Some of these parameters can be measured during the shale drilling/fracking operation to assess impacts in real time, but many will require "before and after" measurements to understand how things might have changed. Another option is to carry out "side-by-side" assessments using a nearby piece of land similar to the parcel being developed as a control. Before and after are better if possible because the effects can be more directly measured..

The Health Effects Institute in Boston, USA has attempted to explore and list the knowledge gaps that remain concerning the potential human health risks from shale gas extraction and fracking. These fall under the three broad categories of 1) sources, 2) transport pathways, and 3) exposed populations[41] (HEI, 2019). Little is known about the probability of environmental releases of hazardous materials from shale gas well sites. Risk of release varies with geology, changes in meteorological conditions, and different practices used by different operators. It can also change over time due to technological innovations, changing regulations, and operator response to community concerns. Environmental monitoring of shale wells would be simplified if indicator chemicals, such as methane in air or TDS in water could be used as predictors of other releases. The mechanism by which a chemical is released into the air or water must be better understood, be it operational, accidental, or illegal.

To have a health effect, a hazardous chemical must not only be released from a source but also transported to expose populations. Local conditions such as meteorology, topography, geochemistry, and hydrology can affect the movement of released chemicals in air and water. An intervention on a transport pathway can stop populations from being exposed to potential chemical health risks. For example, using sandbags to keep a leaking toxic chemical from flowing into a stream that is used for drinking water supplies will prevent many health impacts. Closing a vent to stop VOCs from entering the air during a temperature inversion can prevent the build-up of smog and ozone. In order for this to work, however, the transport pathways must first be identified. If released chemicals can be contained and kept away from vulnerable populations, health risks will be reduced substantially.

Assessing exposed populations is perhaps the most complicated of the three categories of human health risks. Different behaviors can have a substantial influence on how individuals react to potential exposure to frack chemicals. Smoking, alcohol consumption, use of certain drugs, poor eating habits, vitamin deficiencies and many other factors can affect how a person reacts to a chemical. Roughnecks working on the rigs might be expected to be at the greatest risk of exposure, but they are also probably wearing safety gear and have been trained in how to respond to a leak, spill, or other incident. The strenuous nature of the job also requires hiring generally younger people who are in good physical condition. The highest risk populations are more likely to be the very young, the very old, and those who are sick, chronically ill, or otherwise health-compromised. Sub-groups such as small children, pregnant women, and ailing older people may react more adversely to exposures than the general population of healthy, younger people.

[41] HEI (Health Effects Institute), 2019, Human Exposure to Unconventional Oil and Gas Development: A Literature Survey for Research Planning: Special Report 2 (Draft for Public Comment): Boston, HEI-Energy Research Committee, 108 p. (www.hei-energy.org)

7. SUMMATION OF QUESTIONS

Specific questions from the Environmental Defenders Office are addressed in this final section. Answers are summarized here because details have been provided in the body of the report.

a. Describe the Helmerich & Payne super-spec FlexRig Flex 3 Rig and how it differs from previous shale gas drilling rigs that have operated prior to the introduction of the H&P Rig (or equivalent); size of rig, length of drill stem, bottomhole assembly for drilling directional boreholes.

The H&P rig is designed specifically for shale gas drilling. The most notable advancement over the previous large rigs used for shale is the ability to "walk" across the pad to drill multiple directional wells on one site without disassembly and reassembly. The first one of these shale-specific drill rigs that I visited up close was in 2016 when we climbed aboard the Unit Corporation BOSS rig in eastern Colorado shown in figure 4. (During the 2011 visit to the Pennsylvania rig shown in figure 7, we were not allowed to approach any closer than the people in the photo.)

One of the older geologists in the 2016 group and I marveled at the complexity. In the old days, there was a grizzled veteran driller in the dog house with one hand on the throttle and the other on the brake, watching the geolograph, adjusting the RPM and weight on the bit by feeling the vibration through the rig floor, and usually chain-smoking. The BOSS rig had a doghouse as clean as a corporate office, crammed with electronics and video screens, with the techie driller sitting in a command chair and operating the rig using a joystick controller, and definitely not smoking (figure 10). The old rig had roughnecks manually threading and unthreading drill stem joints with chain wrenches; on the BOSS rig it was all done with hydraulic arms under the control of the driller. The amount of data coming back to the driller was phenomenal and data were fed simultaneously to the office some distance away where it was being viewed and preserved. The mud pumps, shale shaker, circulation rate, mud pressure, and just about every other control parameter imaginable showed up on video screens under the direct operation of the driller.



Figure 10: Inside the BOSS rig doghouse with students looking at the driller's viewscreen. Photo by Dan Soeder, 2016.

Shale gas triple rigs like the H&P are bigger than the double rigs used previously for vertical shale wells because the horizontal wells are much longer and require the ability to pull on a longer drill string. The record length of a drill string (to date) is 8.5 km from the surface to the toe of the lateral in the Outlaw C11 H well in the Utica Shale in southeastern Ohio. This length was reported by Eclipse Resources in 2017 and by now may have been exceeded. Laterals this long are improbable in the Velkerri Shale in the Beetaloo basin, but a one km lateral is expected along with a 3 km tophole for a surface-to-toe length of 4 km on the Shenandoah well. The H&P rig will use a steerable bottomhole assembly with a hydraulic powered mud motor to drill directional wells and can be expected to construct multiple wells on a single well pad.

b. How long rigs equivalent to the H&P Rig have been used in onshore shale gas operations in the US;

I first saw triple rigs on the U.S. Gulf Coast in the late 1980s drilling deep vertical wells to reach target reservoirs at depths as great as 6 to 7.5 km. These rigs were used on shale plays beginning with the Barnett Shale in Texas in the late 1990s, when George Mitchell realized he would have to drill long laterals in order to contact enough shale with a wellbore to produce economical amounts of gas. The triple rigs were then used in the subsequent development of the Fayetteville Shale in Arkansas in the early 2000s, the Marcellus Shale in Pennsylvania, and the Bakken Shale in North Dakota in the 2010s. Triple rigs had rarely been used in the Appalachian basin prior to the development of the Marcellus Shale and the first time I saw one in Pennsylvania I was astonished. The modular, shale-specific walking rig designs equivalent to the H&P rig began to appear in the U.S. around 2012-2014.

c. Describe any differences in operation between a previously used shale gas drilling rigs and the H&P Rig (or equivalent) especially:

i. Staff required to operate rig;

The staff required to operate a shale rig like the H&P compared to previously used shale drilling rigs is essentially the same, with perhaps a few less roughnecks because so many of the manual operations have been taken over by hydraulics. Along with a driller, roughnecks, and a mud logger, the H&P rig may have some additional staff, including an IT person to keep the electronics operating, and a geologist to assist with geosteering to keep the borehole on course and in the target formation. The mud logger and geosteering specialist are often the same geologist.

ii. Length of geologic formation (i.e. depth and lateral extent of drilling), extent of fracturing sections, and number of hydraulic fracturing stages;

The number of hydraulic fracturing stages is defined by the length of the lateral. In the U.S., each stage is about 150 m long, so a 1.5 km lateral would have 10 frack stages. The depth of the target shale must be at least 800 m for the hydraulic fractures to break vertically; otherwise they overcome the overburden pressure and pancake into inefficient horizontal fractures. The H&P rig is capable of going quite deep vertically, down to at least 6 km but the targeted Amungee Member of the Velkerri Shale is nowhere near this deep. The Tamboran Resources news release stated that the Shenandoah South 1H well reached a TD of 3,300 meters, with a planned lateral 1 km long. The H&P rig will have no difficulty reaching these depths. They plan to frack 500 m of the lateral in 10 stages, so each stage will only be 50 meters in length. This is a bit intense for fracking compared to U.S. wells, but it is driven by the specific properties of the formation, which of course can be quite different.

iii. Area of land needed for the wellpad;

The wellpad is actually designed to accommodate the sprawling hydraulic fracturing equipment and is much larger than what is needed just for the drill rig (refer back to figure 9). In the U.S., these pads usually occupy 5 acres (2 hectares) and are centered on land parcels of 160 acres (64.75 hectares). With the advent of much longer laterals the pad spacing in many areas has increased to 640 acres, equivalent to one well pad per square mile (2.59 km^2). Greater well spacing is less impactful to the environment. It is important for the issue of land use to not only consider the size of the wellpad but also include service roads that will be required for heavy equipment and pipeline rights-of-way.

iv. Water requirements for hydraulic fracturing and subsequent volume of ponds to store wastewater streams including flowback fluid and produced water (noting that this is likely to be formation-specific);

A hydraulic fracture stage can be estimated to use about 4 million liters (one million gallons) of water. For the 10 planned frack stages of the Shenandoah South 1H well, this is 40 million liters of water. The amount of flowback is uncertain, but it will be less than 100% because some water always stays downhole. Most of the flowback will return soon after fracking, but the formation can give up produced water for quite some time. The design of the evaporation ponds will have to be able to accommodate this. The ponds will also require enough surface area for the evaporation rate to exceed the input rate or they are going to have an overflow problem.

v. Chemical and proppant requirements;

The most common frack fluid chemical additives are methanol, isopropanol, crystalline silica, 2-butoxyethanol, ethylene glycol, hydrotreated petroleum distillates, sodium hydroxide, hydrochloric acid, ammonium chloride, ammonium and sodium persulfate, glutaraldehyde, and polyacrylamide. The additives serve to clean perforations, reduce friction losses, provide corrosion resistance, minimize clay swelling, inhibit scale build-up, and suppress microbes (figure 11).

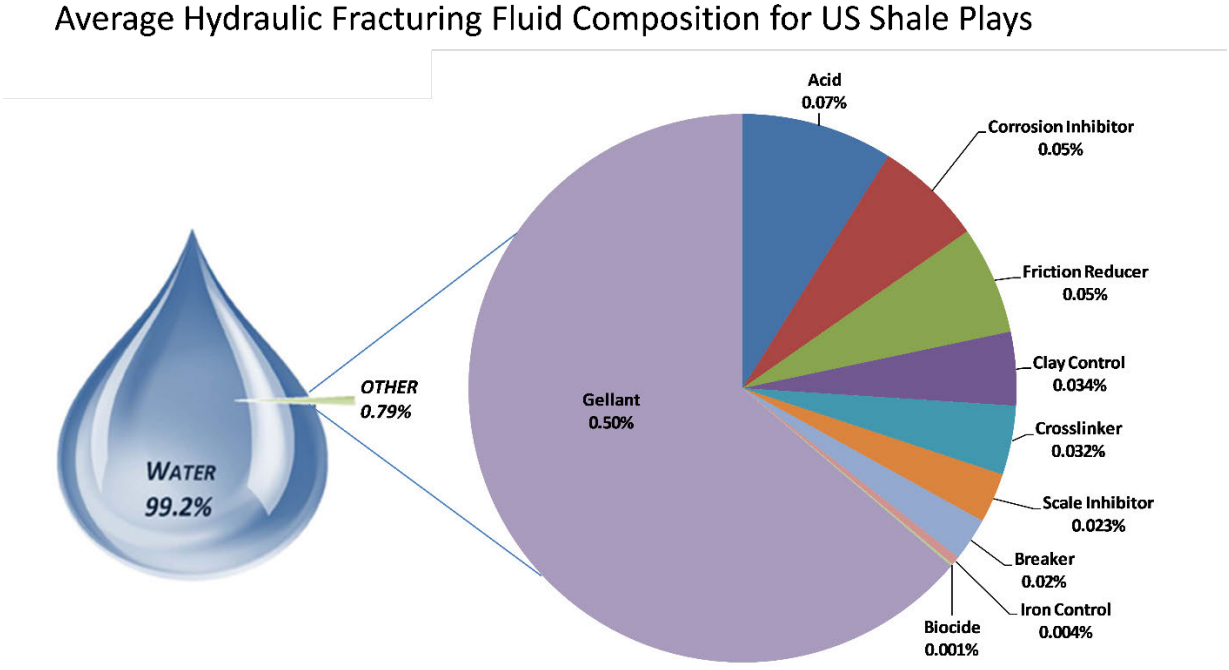


Figure 11: The components of hydraulic fracturing fluid.
Source: Soeder, 2021, Fracking and the Environment (Reference 7).

Chemicals shown in figure 11 that are sometimes added to the frack fluid include a "crosslinked gel," often made from guar gum that thickens up the liquid and helps carry sand into the fracture to act as proppant. In order to get the gel back out after the frack is complete, a "breaker" chemical is added that reduces the viscosity quickly and significantly, allowing it to flow back. Proppant is usually a well-rounded, uniform grain size, high compressive strength silica sand. In the U.S., the Jordan Sandstone in Wisconsin is extensively mined for frack proppant. I do not know what the natural sand options may be available in Australia, but if there are none (and this can be quite challenging because the engineering requirements for proppant are rather stringent) then Tamboran will be forced to either import sand from elsewhere or use one of the manufactured ceramic proppants on the market, both of which are more expensive than using local sand.

vi. Gas emissions (fugitives – greenhouse gases and air toxics, venting and flaring), including what might be emitted longer term from evaporation ponds;

The flowback that returns to the surface immediately after fracking gives off a substantial quantity of methane gas and VOCs. Storing the flowback in open pits allows these gases to vent into the atmosphere, which is not good. This is often done because there is no gas transmission pipeline in place yet. Wells can be drilled but not fracked, or fracked with the fluids kept downhole until a pipeline is run into the vicinity. This gas is known as "stranded," but it is usually just temporary until the well can be brought on production. Once production starts, the gases are mostly contained by the wellsite plumbing system. The compressors then gain first place as the most significant source of methane emissions. The produced water evaporation ponds may add some additional VOCs to the air, and the dissolved solids will precipitate as the water evaporates. At that point, the dried salts are at risk of becoming airborne dust in the wind. Some of the metallic salts and other substances in the dried evaporation tank can be human health risks if inhaled as dust.

vii. Potential for induced seismicity; and

I believe the potential for induced seismicity is low. The Velkerri Shale is described as lithologically equivalent to the Marcellus Shale, composed of siliceous mudstone, siltstone and minor sandstone lithologies. Mudstone is a weak rock that is not normally capable of building up the stresses required for a significant earthquake. If fracking does trigger seismic releases on pre-existing faults, the resulting earthquakes are likely to be quite small. The primary cause of induced seismicity associated with shale gas development is the too-rapid disposal of produced water by underground injection. Since the stated plan for wastewater disposal in the Beetaloo basin is to use evaporation impoundments, this is not a concern.

viii. Any other details that you think may be relevant to explain.

Virtually all of the groundwater contamination and methane gas (flaming faucet) problems during shale gas development in the U.S. were caused by compressed air entering shallow aquifers during tophole drilling. It is important that drillers not use compressed air but drill the vertical part of the well with either water or drilling mud.

d. Please describe relevant studies documenting the probability of spills at the surface during the exploration, drilling, and/or production phase specifically for wellpads where rigs equivalent to the H&P Rig have been used;

A two-state environmental assessment in Ohio and Texas found that gas wells have a rate of "reportable incidents" for environmental violations on the order of 0.5% to 0.1% or less of the total. This translates to one well out of 200 to one well out of 1,000 and includes both unfracked and fracked wells. The majority of these "reportable" incidents are minor, such as incorrect signage or

small spills. Significant violations are rare, but they do happen. More frequent inspections correlated with a lower rate of incidents. Wellbore integrity problems were found to be statistically more frequent in "fracked" versus "unfracked" wells, although the reportable incident rate is similar for both types.

e. Considering your response to c. and d., and/or any other matters you consider relevant, please describe any increased or new environmental impacts and risks, if any, that you believe may arise in the Beetaloo Sub-Basin as a result of using the H&P Rig.

I don't believe the H&P rig *per se* imposes any greatly increased environmental risks in the Beetaloo basin. The rig is specifically designed for shale gas, is engineered to drill deep topholes and long laterals, and is capable of walking across the pad to drill multiple wells without disassembly. Rigs like the H&P have been used in the U.S. for over a decade without major problems.

That being said, there are some real environmental risks and impacts to the Beetaloo basin from shale gas development in general. Landscapes may be affected by the large drill pads. Habitats may be isolated by cross-cutting service roads. Invasive species may hitch rides on drill rigs or the vehicles of workers coming in from great distances. Water supplies in this semi-arid scrubland may be affected by the water demands of high volume hydraulic fracturing. Surface water and groundwater may be contaminated by chemical spills, produced fluids, or leachate from shale cuttings. If they choose to drill the tophole with air, there could be groundwater impacts. Air quality may suffer as toxic dust from dried out evaporation ponds is carried by the wind.

Safeguarding against all of these things is virtually impossible. Risk is a probability multiplied by the consequences, and the best we can do is to try to ensure that high consequence events are also low probability events. Responsible, professional industry players and diligent, independent monitoring can help make that happen.

Despite shrill stories in the media about the environmental terrors of shale gas development, the view on the ground in Pennsylvania, west Texas, and North Dakota (all active areas that I've personally visited) is more nuanced. There have been some problems, but by and large, most of these operations have had few incidents[42]. Most local business are supportive because of the influx of people and money, and the fears of most local residents abated when the promised doom did not befall them. I investigated this extensively as a DOE scientist and when I wrote my book, and discovered that most of the hysteria is not justified. Interestingly, many of the shale gas environmental horror stories were being promoted by Russia Today, especially in Europe where the Kremlin was trying to avoid losing the Russian gas export market to domestic shale gas. I don't know if they are still doing this (I think not-they have other problems) but it certainly was a factor a decade ago.

An over-riding environmental concern is the justification for any fossil fuel development in a greenhouse gas heated, climate challenged world. Tamboran claims the gas will substitute for coal in the domestic power generation sector, thereby cutting Australia's emissions. Natural gas combustion does emit less carbon dioxide than coal, but this can be negatively offset by the fugitive emissions of methane (an even more powerful greenhouse gas) leaking from the gas transmission and distribution

[42] Brantley, S.L., Yoxtheimer, D., Arjmand, S., et al., 2014, Water resource impacts during unconventional shale gas development: The Pennsylvania experience; *International Journal of Coal Geology*, v. 126, p. 140–156.

system. Tamboran should be challenged to perform a lifecycle analysis and place some actual hard numbers on this claim or risk being accused of greenwashing.

I believe that it is entirely possible to develop shale gas in the Beetaloo basin with minimal, manageable environmental impacts. It requires a professional operator who is willing to mitigate environmental risks as much as possible by following best practices, along with diligent monitoring by an outside, independent entity. Knowing that someone is watching greatly encourages industry personnel to adhere to best practices.

Environment Management Plan for the Shenandoah South E&A Program: Potential environmental risks associated with proposed shale gas exploration and appraisal program.

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This report analyses potential risks to groundwater and soils associated with the proposed drilling and hydraulic fracturing of new wells in the eastern Beetaloo Basin by Tamboran Resources, as outlined in their Shenandoah South E&A Program Environmental Management Plan (EMP). The EMP outlines proposed shale gas exploration activities at a site located on exploration permits 76, 98 and 117, across the Shenandoah, Hayfield and Beetaloo stations, between Newcastle Waters and Daly Waters. The proposed activities include:

- Drilling up to 15 horizontal shale gas production wells, and one vertical geological investigation well from four well pads, to intersect the target shale (Velkerri Formation)
- Hydraulic fracturing (fracking) of the 15 horizontal wells, involving between 10 and 60 'stages' (fracking events) for each well, using water sourced from existing and new groundwater bores drilled in the Cambrian Limestone Aquifer (anticipated extraction of ~375 ML/year).
- Testing of the produced gas flow rates and chemistry (for a maximum of 300 days), and the flaring of gas and other hydrocarbons
- Constructing a gathering network of pipelines to allow for the transfer of wastewater (e.g., flowback from fracking the wells) and hydrocarbons between the four well pads (Kyalla 117 N2 and Shenandoah S2 and Shenandoah S B and Shenandoah S C).
- Drilling waste and flowback wastewater management on each site, including storage in open and closed tanks, and transfer of wastewater and solids between different sites. This would encompass construction of sumps for storage of drilling mud, chips and fluids. It is anticipated that the peak volume of flowback water requiring storage would be 34 ML.
- Maintenance, monitoring and decommissioning of wells (as required)

Potential environmental risks associated with these activities considered in this review are:

1. **Depletion of groundwater** through extraction to support hydraulic fracturing of the wells, and impacts on groundwater dependent ecosystems (GDEs) and other water users
2. **Contamination of soil and groundwater** through:
   - Inter-aquifer leakage of contaminating fluids (including fugitive hydrocarbon migration), through either natural features, such as faults and fractures, or through well integrity breaches;
   - Surface spills and leaks of fracking chemicals, drilling fluids, flowback water and/or hydrocarbons produced by the wells;
   - Leaching and release of contaminants from waste brines produced during treatment of flowback water and other solid wastes generated on site (e.g. drill cuttings and drilling fluid residues)
3. **Seismicity** - e.g., fault activation that occurs during fracking, triggering increased seismic activity

In the EMP, Tamboran assess a range of possible environmental risks and arrive at a risk rating of 'Medium' for 16 possible environmental risks and 'Low' for 74 risks associated with the proposed activities. None of the activities are assessed in the EMP as having high or very high risk:

Table 7: Summary of risk ratings with environmental controls applied

	Environmental risk rating with applied controls			
	Low	Medium	High	Very high
Total 90	74	16	0	0

Among the risks assessed to be 'medium' include contamination of surface water and contamination of soil due to spills and leaks of chemicals, wastes or wastewater.

It is argued that the risk(s) of impacting the groundwater system and its ability to support ecological, economic and community activities is low. Largely, this rating was given due to the proposed use of mandatory well integrity safeguards (e.g., cementing of the shale gas wells' annular space between the casing and adjacent high-value aquifers), and due to the relatively deep water tables in the area, increasing the time it would take for contaminants to reach the water table aquifer.

However, given the information provided in the EMP and the current level of knowledge of the hydrogeological system(s) of the area, the likelihood of groundwater contamination should be considered at this stage to be poorly known, and the risk(s) of impacting groundwater quality may be higher than estimated in the EMP.

Water depletion associated with extraction from the Cambrian Limestone aquifer to support hydraulic fracturing may also have been under-estimated, due to limited ability to recycle flow-back water between wells (the potential for flowback recycling at one of Tamboran's other exploration sites, was recently found to be limited – see Currell, 2023). The groundwater depletion risk associated with the proposed hydraulic fracturing may have been under-estimated if this is the case. These issues are discussed in further detail below.

Groundwater and soil contamination risk

Tamboran's risk assessment notes that drilling and fracking for the type of shale gas resources present in the Beetaloo Basin, is typically understood to bring 'high consequence, low likelihood' risks, including the contamination of high-quality (potentially potable) groundwater resources near the well sites. It is argued in the EMP that the application of mandatory well integrity safeguards, such as isolation barriers (cement between the wells and high-value aquifers they pass through), will reduce the likelihood of such events to 'as low as reasonably practicable'.

However, it can be argued that groundwater contamination risks are substantially greater than the EMP has concluded, due to the following factors:

1. There is currently a relatively limited understanding of geological structures, rock properties and the biogeochemical environment in which the proposed fracking would take place - all of which are critical to a full assessment of well integrity risks. The EMP does not include detailed site-specific analysis of likely permeability and other rock properties of the different units, or analysis of biogeochemical conditions. Table 35 provides a simplified stratigraphy of the site, based on a deep well drilled nearby (Kyalla 117 N2). However, the depth of the target Vekerri Formation shales (listed as between 700 to 900 m) appears to be approximate only, and it is unclear whether key units between the target shales and high-value aquifer(s) – e.g. Gum Ridge Formation - are likely to act as effective aquitards or aquifers, particularly the Bukalara Sandstone and Antrim Plateau Volcanics.

Currell and Ndehedehe 2023, who reviewed the recent SREBA reports addressing the recommendations of the Scientific Inquiry into Hydraulic Fracturing in the NT (Pepper Inquiry), identified that despite the studies conducted over the past 5 years for both the SREBA and Bioregional Assessment programs, there remains a general lack of understanding of inter-aquifer connectivity between the Beetaloo basin sedimentary rocks, and shallow, high-value Cambrian Limestone Aquifer throughout Beetaloo region. The SREBA program involved hydraulic testing to examine deep-shallow inter-aquifer connectivity between the (deep) Bukalara Sandstone and (shallow) Cambrian Limestone aquifer (Short, 2021), which showed minimal connectivity over the period monitored; however, multi-level aquifer monitoring and hydrochemistry data indicated likely connectivity between these same units in the eastern Beetaloo Basin, due to the absence of a significant aquitard between the formations in this area (Tickell, 2022). The level of connectivity between shallow and deep formations is thus variable, and without site-specific hydraulic testing to explore deep-shallow aquifer connectivity at the Shenandoah South site, it is not possible to say whether such connectivity is likely to be significant or not.

Inter-aquifer connectivity is a significant issue as it affects the potential for hydrocarbons to migrate from the target shale resources into shallower aquifers, particularly in the event of well integrity breaches. Examples where this has led to methane contamination of high-value shallow groundwater resources include Osborn et al., 2011; Jackson et al., 2013, Darrah et al., 2014, Llewellyn et al., 2015 and Whyte et al., 2021.

2. The experimental nature of the proposed fracking during exploration and appraisal heightens the risk of unexpected events which may result in environmental harm (e.g., well blow-outs and other well integrity failures, induced seismicity, spills and leaks of flowback water or other wastes). In the 'key objectives' of the EMP it is stated that the proposed drilling and testing of the horizontal wells would be used to determine well interference distances and experiment with 'different stimulation fluid systems or other variables' to improve gas production. Conducting such experimentation in an environment where there is limited information about rock permeability and geomechanical properties, inter-aquifer connectivity, and biogeochemical environment (which will influence the risk of corrosion and/or clogging of wells) mean that it is not possible to unequivocally assign a 'low' likelihood to well integrity risks. Davies et al., (2014) found that, according to global databases, integrity failures occur in approximately 2 to 75% of oil and gas wells over their lifetime. Taking the Marcellus Shale (a major unconventional shale gas resource in the US) as an example, 6.3% of wells reported well barrier or integrity failures in the period examined by Davies et al. The Marcellus has many thousands of wells installed and relatively detailed documentation of well integrity and other environmental violations, meaning these rates are likely indicative of typical shale gas developments (although site specific conditions will influence failure rate). Applying this rate to the Shenandoah South site would suggest that at least one of the 15 horizontal wells will be likely to experience an integrity issue over the period of the EMP.

   Recent data from exploratory fracking conducted at another site operated by Tamboran (Amungee 2H well) in the same shale formation, indicated that fluid recovery was substantially less than was originally anticipated – with only approximately 10% flowback recovered (compared to industry estimates presented to the Pepper Inquiry of 20 to 50%). This may have been related to the presence of a geological structure, such as a fault or major fracture, the intersection of which could increase the risk of triggering seismic events and/or compromising

the well casing (Llewellyn et al., 2015). An earlier fracking trial at a nearby well (Amungee 1H) conducted by Origin, experienced a 'casing deformation event' that compromised well integrity, and this was thought to be related to the intersection of a geological structure (Origin, 2021). During Tamboran's recent fracking trials, the Amungee 2H well also became blocked, due to the development of a 'skin' – likely to be a result of rapid and extensive growth of bacterial colonies and associated biofilms/precipitates (Hannam & Partners, 2023). Such growth can - in addition to well blockage, be associated with well corrosion, and in serious cases, well failure (this is discussed further in Currell, 2023). Taking this into consideration, the conclusion of a 'remote' possibility of well integrity issues at the site, which may result in groundwater contamination, particularly with hydrocarbons, should be carefully re-assessed.

3. The likelihood of spills and leaks of fracking wastewater has likely been under-estimated. A review by Patterson et al. (2017) of tens of thousands of shale gas wells across four US states indicated that spills of potentially contaminating fluids from unconventional gas (particularly flowback water) occur at rates of between 2 and 16% of active wells per year, with the majority occurring in the first three years of a well's life. Spills are associated with equipment failure, human error and environmental conditions (e.g. extreme weather). Approximately half of spills documented by Patterson et al. were associated with storage and transport of fluids through flow-lines. The fluid and gathering line network proposed to be constructed at the Shenandoah South site will be subject to 'months' of fluid transport in above-ground lines exposed to environmental conditions (see p. 63 of the EMP) as well as transfer of fluids in buried pipelines within trenches. Given the leakage and spill rates observed in the US shale gas industry, it should be considered highly likely that there will be incidents of this kind occurring over the proposed 5-year operation of the E&A program. Using the lower and upper rates determined in Patterson et al., 2017 and assuming each well is in operation for three years, a total of 1 to 7 spills or leaks would be anticipated to occur over the life of the EMP. Releases of either fracking chemicals stored or transported around the site, or flowback water produced from the wells – which is concentrated in salts, hydrocarbons and certain metals (see Table 20, reproduced below) would both pose a considerable hazard to soil quality and in the longer-term (via infiltration through the unsaturated zone), groundwater quality.

Table 20: Indicative flowback quality based on Amungee NW-1H flowback results

Parameter	Flowback levels
BTEX compounds	Total BTEX levels are anticipated to be low. Total BTEX in the Amungee NW-1 in flowback ranged between 2 and 15 µg/L
Total nitrogen (as N)	Maximum value of 62.1 mg/l observed within flowback
Salinity (TDS)	Saline with total dissolved solids level exceeding 49,000 mg/L
pH	Slightly acidic with a median value of 6.74
Major ions	Flowback predominantly Na and Cl dominated
Dissolved metals	All detected dissolved metal concentrations within the flowback were low, except for barium 54.5 mg/L) and boron (80.1 mg/L)
Polycyclic Aromatic Hydrocarbons (PAH)	All values in the flowback below laboratory Limit of Reporting (LOR)
Petroleum hydrocarbons	All fractions of TPH are anticipated to be elevated
Phenolic compounds	Low level of phenolic compounds detected in flowback
Radionuclides	Maximum Gross Alpha Activity and Gross Beta Activity of 12.4 Bq/L and 18.3 Bq/L encountered in the flowback, the anticipated source is likely to be radium-226

4. Analysis of risks associated with fracking chemicals (and their by-products) appears to be incomplete. The EMP includes a list of chemicals and their anticipated volumes likely to be used in the proposed fracking. This includes a wide range of acids and bases, biocides, surfactants, placticisers, scaling and corrosion inhibitors. Among the list are a number of 'proprietary' compounds whose names do not describe the specific molecule / compound (e.g. these have codes, mostly assigned by contractor Halliburton, beginning DCA- and BE-).

   Chemical risk assessments for hydraulic fracturing and flowback fluids are provided as Appendix E and E.1 of the EMP. It appears that the original chemical risk assessment (conducted by AECOM) examined a set of typical chemicals used in typical hydraulic fracturing fluid formulations, and this did not include all specific chemicals proposed to be used at the Shenandoah South site (listed in Table 6 of the EMP). Two of the chemicals with DCA codes (DCA-32002 and DCA-32014) appear in the Toxicity Summaries information; but there are a further eleven compounds with the DCA- code where it is unclear whether the chemical has been assessed. The names of the specific chemical compounds (or mixtures thereof) and their associated code numbers need to be clearly identified and explained, to allow for cross-checking and verification of the completeness of the risk assessment. Multiple other chemicals listed in Table 6 of the EMP do not appear in the Tier 1 or Tier 2 assessments in Appendix E.

   The second chemical risk assessment - Appendix E.1, by EHS Support, includes a wider range of compounds, including most chemicals listed in Table 6 of the EMP that aren't included in Appendix E. However, the list was based on information previously provided in EMPs prepared by Origin Energy (the former holder of the petroleum leases at the site), and it is still unclear whether all compounds with the 'DCA' codes have been assessed in this document, due to lack of explanation of the codes.

   A web search identified one of the compounds with a letter code 'BE-9 biocide' to be Tributyl tetradecyl phosphonium chloride – a compound with very high acute toxicity, and for which biodegradation information is currently not available. On this basis, it should be considered that the use of this compound may present a high risk to human and/or environmental health, that has not been comprehensively explored in the risk assessment.

   It is also unclear whether breakdown products of the chemicals proposed to be used in the fracking mixtures have been identified and analysed for potential toxicity in the risk assessment. This is important, as some chemical compounds may degrade into more toxic daughter products. It should be noted that many of the chemicals proposed to be used in the fracking process (listed in Table 6 of the EMP) are salts of ammonia and boron, which ultimately break down to release these ions, resulting in high ammonia and boron concentrations in the residual fluid (hence flowback water is expected to be highly enriched in these ions). These breakdown products can be toxic to aquatic and terrestrial organisms, and there are examples of their release into the environment associated with shale gas flowback in other regions, such as the US (e.g., Harkness et al., 2015). As such, these should have been carefully analysed in the chemical risk assessment, along with the primary compounds proposed to be utilised in the hydraulic fracturing process. The same applies to all inorganic and organic chemicals that may form from the breakdown of primary chemicals used in fracking.

An additional group of compounds that warrant chemical risk assessment are the Per- and poly-fluoroalkyl substances (PFAS), which have been found to have contaminated groundwater in are areas of oil and gas development in the United States (Siegel et al., 2023). PFAS are used in oil and gas as corrosion inhibitors, for enhancing evaporation and as water-proofing agents for many types of site infrastructure. While the chemicals may not be directly used in fracking fluid mixtures in this case (although this should be confirmed by the proponent), there are many materials and substances that may be introduced to the site in the process of drilling, storage and transport of fluids and wastes, that may contain PFAS, that could leach into the surrounding soils and groundwater incidentally during site development and operation. A careful analysis of potential PFAS sources in the materials planned to be used at the site is therefore important.

Both of the chemical risk assessments (Appendix E and E.1), examined potential exposure pathways for hydraulic fracturing chemicals associated with EMP activities, as part of the Tier 2 assessment. This analysis found only one complete pathway – the on-site release of particulates and vapour during chemical mixing and flowback evaporation (due to human error) by which human or environmental exposure to fracking chemicals may occur.

Other pathways for release of the chemicals to the environment, particularly spills and leaks of fracking fluid mixtures and flowback water, both on-site and offsite (e.g. during transport in gathering lines, tanks and pipelines), are not considered to be complete pathways in the assessment. This is due to the proposed implementation of controls, which are considered to reduce the probability of spills to 'remote'. However, this finding is inconsistent with the empirical data described above from the US shale gas industry, which identified spill rates to be between 2 and 16% of active unconventional gas wells (Patterson et al., 2017). Spill rates are highest in the first three years of a shale gas well's life – in this case, three years is the full proposed life of the wells. Even with multiple controls in place through the spills management plan (Appendix H), the assumption that spills of fracturing fluids and flowback water will be 'remote' appears overly optimistic, and likely under-estimates the potential for release of fracking fluid mixtures and/or flowback water to the surrounding environment. Due to its chemical composition (see Table 20), any release of such fluids is highly likely to cause harm to the nearby environment, particularly within soils, but potentially also surface water and (in the longer-term), groundwater.

5. Spills and leaks prevention and mitigation plans are not sufficiently detailed and cannot safeguard against release of hazardous wastes to the environment. One of the key risks associated with the EMP proposal is the use of evaporation as the primary method of on-site wastewater management. The use of evaporation dams to manage wastewater from unconventional gas is not permitted in other jurisdictions, such as Queensland (which has a large coal seam gas industry) and New South Wales. Flowback water from the target shale formation (Velkerri shale) is expected to be saline and enriched in hydrocarbons, ammonium, radionuclides, barium and boron (see table 20), and these elements would be further concentrated in the residual liquid and residues, as evaporation proceeds. Any environmental receptors exposed to this material - soils, surface water and (eventually) groundwater would be likely to experience harm.

   Open storages, in which evaporative enrichment is proposed, are vulnerable to overflow and leakage during extreme weather events (through heavy rainfall and/or damage from high winds and wind-blown debris). While the EMP includes design elements that are intended to reduce the risk of overflow from open tanks used to store and evaporate flowback water and other wastes, the risk cannot be fully eliminated by the proposed design and control measures. Daily

rainfall data for nearby BOM stations (e.g. Hayfield, 014656) indicate that the area where the wells are proposed periodically experiences major rainfall - e.g., events exceeding 50 mm in a day, not just in the rainy season (in which events exceeding 100 mm/d are not uncommon) but also in other months (e.g. the highest daily rainfall recorded in June at this station is 83 mm).

Such weather events would greatly increase the risk of overflow or leakage from open storages. While there are contingency plans outlined in the EMP to transfer wastewater out of open storages in advance of forecast large rain events, the size and timing of such events may not always be accurately forecast far enough in advance to allow for effective prevention of leaks and spills. The increasing frequency of extreme weather events associated with a changing climate means that using the standard ARI methods to estimate required freeboard and other design elements for storage tanks may not sufficiently mitigate risks of failure.

Evidence of soil contamination associated with drilling waste at another Tamboran shale gas exploration site at Tanumbirini Station (McCutcheon, 2023) indicates that risks associated with storage of unconventional gas waste products are real and tangible, and that the management of these wastes at shale gas well sites in the Northern Territory presents significant challenges (e.g. unexpected weather conditions). Contamination of the environment may not always be able to be avoided in such cases.

6. Long-term hazardous solid and liquid waste management plans are not fully developed. The EMP includes a simple analysis of options for the long-term management of solid and liquid wastes, which will include certain waste streams that have no viable disposal option except for off-site disposal in a 'licenced facility'. These waste streams include residual brines left over after flowback water is evaporated, drilling waste that cannot be safely disposed on the well pad sites and soil and water contaminated by spills (Table 27).

   Further details are required regarding the end destination for such contaminated materials – e.g., if there are one or more facilities currently licenced to accept these types of hazardous wastes, then these should be identified, and the relevant standards and criteria for safe off-site disposal discussed. Otherwise, it should be considered that the proposal will potentially produce a legacy of hazardous wastes that may pose an ongoing risk to the environment – e.g., soil, surface water and in the long-term, groundwater, with no viable long-term plan to successfully isolate these materials.

Groundwater requirements of the proposal, and risk of groundwater depletion

The EMP includes a plan to increase current licenced groundwater extraction from 175 ML/year to 375 ML/year and drill up to 8 new groundwater monitoring/extraction bores at each well pad site (up to a total of 24 new bores in the Cambrian Limestone Aquifer). Modelling of groundwater extraction at the anticipated extraction rate indicates that drawdown at distance of 1 km from the extraction bores is likely to be <1 m, which is considered to be a minimal impact. However, it should be noted that the modelling does predict drawdowns of ~0.4 m to occur 7 km away from the point(s) of extraction (Figure 31). While drawdowns of this magnitude are unlikely to compromise bore function, they may have a noticeable impact on yields from water supply bores, which are important for the pastoral industry in the region. A bore search within a 10 km radius of the site is not included in the EMP, but a preliminary search using the NT government's bore database found bores within approximately 7 km of the proposed well pads - e.g. pastoral bore RN034480, Shenandoah station, RN023330, Hayfield Station and RN040745, which may be affected by drawdown.

Water level drawdown may also be associated with increased leakage of water from above or below into the target aquifer, which may have water quality implications. This appears not to have been assessed. The groundwater extraction will also reduce the flux of water (in the long term) leaving the region as groundwater throughflow and/or discharge, changing the aquifer water balance. The CLA is a high value aquifer, connected over large distances, and supporting significant groundwater dependent ecosystems (GDEs), including springs and stygofauna (Currell and Ndehedehe, 2022). As such, any changes to the groundwater flow regime and discharge rates need to be considered carefully encompassing cumulative effects of other current and proposed extraction activities.

Further, it is possible that groundwater requirements of the proposed program (and thus drawdown associated with extraction) may be higher than the anticipated 375 ML/year. The rates required to conduct hydraulic fracturing are estimated assuming that there is potential to recycle flowback water in successive fracking events. However, as discussed above, recent fracking trials at Tamboran's Amungee 2H well site involved loss of approximately 90% of the fracking fluid, which was attributed (by Tamboran) to the shale being highly 'dessicated' (see review report by Currell, 2023). If similar or lower rates of flowback recovery occur at the Shenandoah South wells, then greater volumes of groundwater will be required to allow fracking to proceed, as less flowback will be available to re-use in successive fracking events. As such, consideration of the impacts of extraction at a range of rates, including higher than the anticipated rate, should have been conducted and simulated in drawdown modelling, and the water balance impacts and potential to influence GDEs, explored further.

Only one figure showing the output of drawdown modelling is included in the EMP for the purposes of assessing potential groundwater depletion impacts. Further documentation of modelling methods and assumptions is required, together with presentation of results as maps, for multiple extraction scenarios (e.g. the full volume extracted at one site or spread over multiple wells, a range of different extraction rates spread over the 5 years of the plan). This is needed to enable full analysis of the likely robustness of the drawdown estimates and the assessment of risks to groundwater users and GDEs.

Proposed groundwater monitoring program

The monitoring program in Table 30 includes the proposed monitoring of groundwater levels continuously in the lead-up to and following hydraulic fracturing events. This would, provided monitoring is conducted in a sufficient number of bores, allow for rapid detection of any fracking-related impacts on the groundwater levels in the aquifer system. It is recommended that, for both water quality and level purposes, monitoring take place not just in the high value CLA aquifer, but also in intervening units between the target shales and the CLA (e.g. Antrim Plateau Volcanics and Bukalara Sandstone). Only by doing so will potential early warning signs of impact be able to be identified.

A major deficiency in the groundwater quality monitoring program proposed is the relatively infrequent sampling schedule. Sampling for water quality is only proposed to occur quarterly, prior to and after fracking events. Such infrequent sampling is unlikely to identify rapid changes in water quality associated with hydraulic fracturing and other site activities. Sampling should instead be conducted immediately before, during and after fracking events, at high frequency (e.g., daily), to ensure adverse water quality impacts that may occur during this time are effectively identified, and appropriate measures to protect groundwater quality can be rapidly enacted. More generally, given the potentially high consequences of any fracking, drilling or flowback fluids contaminating the shallow CLA aquifer (which contains high quality groundwater), more frequent sampling for water quality is needed together with a detailed list of analytes to be measured – encompassing key chemical of high toxicity used in the fracking process. The current proposed monitoring program thus appears to be under-

developed, and not sufficiently robust to ensure any water quality impacts associated with site activities are rapidly and accurately identified.

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To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan
Date: Tuesday, 12 December 2023 3:47:51 PM

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Woodward

Location

DARWIN, NT

Stakeholder type

Community member

Email address

woodwardlou@hotmail.com

Interest area

Climate change
Chemicals
Human health

Please provide your comments

Hydraulic fracturing of shale formations causes harms to human health through known toxins in the fracking fluid and wastewater including carcinogens, endocrine disruptors, heavy metals and radioactive chemicals. Improper disposal of wastewater, alternative uses of wastewater for dust suppression or livestock watering, accidents, contamination of ground water or through fractures in the aquifer introduces chemicals and toxins into the water. Venting and emissions of chemicals such as BTEX chemicals are known to exist in shale rock and can be released into the air through fracking. Populations living near these chemicals and toxins are known to suffer from increased rates of asthma, cancer, and death, as well as miscarriage, birth defects, preterm birth, and low birth weight. The research showing harmful effects to the health of resident populations can no longer be ignored as it is only getting more robust. Climate change is caused by the release of methane through fracking and the burning of fossil fuels. Fracking the Beetaloo Basin will drive climate change. The world is at or close to tipping points where the environmental effects may become uncontrollable and catastrophic. The NT is on the frontline of climate change and will suffer the consequences earlier than other jurisdictions. It is unethical to proceed with hydraulic fracturing in the Beetaloo Basin with the current level of evidence of harm to local populations and to the citizens of the NT and Australia as a result of climate change. I have attached a comprehensive report into the health impacts of the oil and gas industry which can be used as a detailed reference. It was published in September 2023 and is the most up to date source of medical information having been published after the Pepper enquiry.

Add an attachment - Max file size: 5MB

https://s3-ap-southeast-2.amazonaws.com/ehq-production-australia/6034629d171899f2c6ce54ac91c4d0a9a3fbee4a/original/1702361376/1331dbeadf17ed32a597b21dd9c2adb1_risks_of_og_development_%282%29.pdf?1702361376

[redacted]

From: Have Your Say Northern Territory <notifications@engagementhq.com>
Sent: Tuesday, 9 January 2024 2:23 PM
To: tamboran DEPWS
Subject: Anonymous User completed Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

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Anonymous User just submitted the survey Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan with the responses below.

Given name

Amanda

Family Name

Lilleyman

Location

NIGHTCLIFF, NT

Stakeholder type

Community member

Email address

amanda.lilleyman.bird@gmail.com

Interest area

Climate change
Flora and fauna
Social and cultural
Water
Human health

Please provide your comments

My name is Dr Amanda Lilleyman and I am an ornithologist based in the Northern Territory with 15 years' experience in bird survey and analysis. I am concerned that the activities outlined in the Tamboran Environmental Management Plan for the proposed Shenandoah South E&A program for shales will impact the people of the Northern Territory through impacts to health, degradation of the environment, the use of toxic chemicals in the environment, impacts to the climate and warming from shale well exploration and any associated fracking activities. It is also concerning that under section 4.2.3 Fauna, there is a statement that proposed disturbance areas had high native grass cover and included species suitable for granivorous birds. Granivorous birds in the area might include the Northern Shrike-tit and Gouldian Finch, both threatened species. It should be considered unacceptable for Tamboran to disturb any ground cover or vegetation that disrupts access to these tree resources. It appears as though fauna surveys were conducted in April 2023; this means that there is a chance that some wildlife species using the area at other times of the year were not considered and therefore the area may be undervalued for other species. It is inadequate to survey for threatened species at on location during one month of a year. Table 50 lists the EPBC Act species, including Red Goshawk and states that there is "no suitable breeding habitat within the project area", but it is likely that there is suitable foraging habitat available in the project area, thus the likelihood of occurrence should not be listed as "unlikely". Access to suitable foraging habitat for a wide-moving species such as the Red Goshawk is vital to the species existence as it requires large stands of intact savanna woodland. The closest record of the Gouldian Finch is 75 km from the project area, and it is known that this species moves across landscapes in search of suitable foraging habitat. I recommend that the likelihood of occurrence be changed from "possible" to "likely". This assessment should not be completed under the guise of convenience to the proponent, it needs to stand alone for the environment and the species that are likely to be impacted. I am concerned about birds and other wildlife accessing wastewater ponds, concerned that the literature referenced for this in the EMP (page 115 for example) are old and outdated, indicating that there may not be recent investigations into this matter. There is evidence from wastewater ponds from cyanide dam tailings resulting in mortality of migratory shorebirds elsewhere in Australia. This information is available in grey literature in consultant reports. Please investigate this matter and take it seriously as these are National Matters of Environmental Significance. Further to this, it is concerning that a large swathe of suitable literature has not been used to draw conclusions in this EMP. I can see that the authors used an outdated version of The Action Plan for Australian Birds 2010. There is a 202 version and that should be consulted and referred to instead of the 2010 version. In your acronym list, you list IBA = Important Bird Area, but this term is not only outdated and superseded by Key Biodiversity Area, but it is also not used in the EMP, so it has not place in the acronym list. Under section 2.1 Ecological Sustainable Development - there is a claim that the activities listed in the EMP do not constitute threats of serious or irreversible environmental damage. This claim cannot be substantiated as fracking in the Beetaloo Basin will increase the effects of climate change causing serious damage to the environment and human health through an increase to human health risks and impacts, and damages the environment. The royalty payments for the natural resources that are proposed for extraction are not adequate as the NT Government is not the owner of those resources, it is the community that is the owner. The people of the NT are not being compensated for proposed fracking activities and will not benefit from these activities. Regards, Dr Amanda Lilleyman 9/1/2024

[redacted]

From: Hannah Ekin <hannah.ekin@alec.org.au>
Sent: Monday, 8 January 2024 8:01 PM
To: tamboran DEPWS
Subject: Arid Lands Environment Centre Submission re Tamboran EP98 and 117 EMP
Attachments: Arid Lands environment Centre EMP Tamboran EP98 and 117 submission.pdf

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see our attached submission.

Kind regards,

--
Hannah Ekin
Frack Free Campaigner,
Arid Lands Environment Centre
+61491283520
I work Monday - Thursday but you can always call my mobile if urgent
my pronouns are she/her

I acknowledge the Arrernte people as the custodians of the land on which I live and work. Across this continent, this always was and always will be Aboriginal land.

Arid Lands Environment Centre

Office: Gap Road, The Gap 0870 NT
Phone: 08 89522497
Email: frackfree@alec.org.au
Web: www.alec.org.au
Mail: PO Box 2796 Alice Springs 0870 NT

8th January, 2024

Submission on: Beetaloo Basin Shenandoah South E&A Program EP98 and EP117 Environment Management Plan

Addressed to: Department of Environment, Parks and Water Security, Petroleum Operations Unit

By email: TAM1.EP98+117@nt.gov.au

The Arid Lands Environment Centre (ALEC) is Central Australia's peak environmental organisation that has been advocating for the protection of nature and growing sustainable communities in the arid lands since 1980. ALEC actively contributes to the development of energy policy and planning through written submissions to policy reform and approval processes, engagement with local and affected communities and education. 2 ALEC welcome the opportunity to provide comment on Tamboran resources' Shenandoah South E&A Program EP98 and EP117 Environment Management Plan.

ALEC submit that this EMP does meet the approval criteria outlined in section 9 of the *Petroleum (Environment) Regulation 2016* and should be refused based on it's inadequate description of the climate impacts and groundwater contamination risks of the project and how these will meet be reduced to ALARP as required.

Note: These are just the two most significant problems we have identified with this EMP based on preliminary read. The timing of this submission period over the Christmas and new year shut down period has made it impossible for us to give this 3600 page application the full scrutiny it warrants, and we are concerned there are other risks and impacts that we have not had a chance to identify.

We strongly suggest that for the EMP process to meet its aims of allowing affected stakeholders to comment, the 28 calendar day public comment period must be reformed to be 28 business days, or not include the department's Christmas shutdown period. In the meantime, we have identified too major areas of concern where this EMP does not meet the requirements of the act. As a result of these omissions, we submit that the Minister cannot reasonably be satisfied that the EMP meets the approval criteria under the *PE Regulations*, and cannot lawfully decide to approve the EMP.

Greenhouse Gas Emissions:

The EMP doesn't adequately address the environmental risks associated with the greenhouse gas emissions it will cause. The information provided on the greenhouse gas emissions that this project would cause is incomplete and inaccurate. Its emissions estimates are rely on a "flare avoidance program that is not part of the EMP and has not been committed to by the proponent.

The proponent invokes lifecycle greenhouse emissions benefits of gas replacing coal in the abstract, but doesn't assess the full lifecycle emissions from the project, including that of downstream "beneficial use" of gas if pursued, emissions from sand mining for proppant, and of the transportation of wastewater and "beneficial use" gas.

The EMP also claims the activities "do not constitute threats of serious or irreversible environmental damage and there is no impact on the conservation of biological diversity and ecological integrity" (page 35). We submit that the proponent can only have come to this conclusion on the basis of the willfully incomplete assessment that has been made, particularly with regard to the impacts of climate change which are already at the threshold of inflicting serious and irreversible environmental damage, impacting on biological diversity and ecological integrity. Relevantly, there is considerable evidence available that global average temperature rise is near to passing the threshold of 1.5 degrees above pre-industrial levels, and institutions such as the International Energy Agency (IEA) have concluded that to prevent this threshold being breached, there is no room for new gas production anywhere in the world.

Wastewater: The parts of the EMP which deal with wastewater management fail to demonstrate that the environmental risks of the activity will be reduced to an acceptable level.

The management system for the waste water flow lines is not adequately described, and does not meet the requirement for "an auditable chain of custody system" for wastewater tracking laid out in the *Code of Practice: Onshore Petroleum Activities in the Northern Territory.*

The EMP envisages 8.5km of piping above and below ground in an elaborate multi-site wastewater management scheme. It is not clear whether this system will only be used for certain types of wastewater or if a single system will be used for flowback water, produced water and drilling fluid waste.

This is a high risk proposal not described in any real detail and cannot be approved. It is claimed in Appendix H that "All the proposed activities for the exploration program are planned during the dry season" but also that "Where activities occur outside, Tamboran's Wet Weather Contingency Plan will be implemented". This contingency plan is not provided; instead, the proponent indicates it will create the plan and submit as a revision of the EMP in October (Appendix H page 29)

The *Water Act 1992* prohibits fracking wastewater releases to surface water bodies under section 17A. The EMP claims in its summary that "No wastewater release to surface water

proposed" but elsewhere contemplates "Most of the water will be re-used, with any unused groundwater released through a controlled discharge to the area surrounding the lease pad". At least one unintended release of wastewater has already occurred on an exploration site operated by this proponent and the EMP does not provide adequate controls to prevent this from occurring again.

The need for this proposal to be referred to the EPA for assessment.

This proposal has not been submitted to the EPA for assessment by the proponent itself. You, as the relevant decision maker, have the power to refuse to consider the application until the action is referred to the NT EPA and a decision is made on referral.

The proponent, in its EMP states claims: "Tamboran has completed a self-assessment. The level of potential environmental impact is not considered significant." Given the scale and magnitude of the regulated activities being proposed, including land clearing, exploration through fracking, complex wastewater management systems and hazardous chemicals handling. Each of these activities which have the potential to cause a significant impact to the environment are required to be referred to the EPA for assessment under the *Environment Protection Act 2019*.

ALEC believe that this application does not meet the requirements of the EMP approval process, does not demonstrate that risks to the environment have been adequately mitigated or managed and as such should be refused by the minister.

Kind regards, Hannah Ekin

Frack Free Campaigner, Arid lands Environment Centre.

From: Eugenie Collyer
To: tamboran DEPWS
Subject: Request extension
Date: Monday, 18 December 2023 7:47:33 AM

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Please extend the time allowed for comments on the EMP recently submitted by Tamboran to honour this: "The department is committed to ensuring that as many Territorians as possible are aware of, and have an opportunity to comment on, these EMPs."
Thanks, Eugenie Collyer.

[redacted]

From: Louise Woodward <woodwardlou@hotmail.com>
Sent: Tuesday, 9 January 2024 4:12 PM
To: tamboran DEPWS; Onshoregas DEPWS
Subject: Submission on Tamboran EMP from NT Paediatricians
Attachments: Final EMP Tamboran submission.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Dear Onshore Petroleum Assessments,

Please find attached the submission for the draft EMP from Tamboran which has a closing deadline of Tues 9th Jan at midnight.

It was most disappointing to find the portal link had disappeared when I tried to submit our submission at 3pm Darwin time on 9th Jan which was well before the deadline. When I tried to ring the number listed on the submissions instructions page, it was the wrong number. I was given a different phone number to call but no one answered and no one has returned my call. There is only a generic email on the webpage which I am told is not the right email address for submissions.

This is most unsatisfactory, particularly as many members of the public have taken time out of their Christmas holidays to complete submissions.

Regards,

Dr Louise Woodward
Paediatrician
pH 0405531576
8 Johns Place
Rapid Creek

2024

Submission on Petroleum EMP by Tamboran B2 Pty Ltd

NT PAEDIATRICIANS AND PUBLIC HEALTH ASSOCIATION OF AUSTRALIA, NT BRANCH

DR LOUISE WOODWARD, DR PAUL BAUERT, DR SIMONE MARTIN, DR ROSIE ROCK, DR ANNIE WHYBOURNE, DR MIKE FORRESTER, DR ROSALIE SCHULTZ, DR CATHERINE PENDREY, DR KATHERINE BARRACLOUGH, AND MS LILY PRATT

Northern Territory Paediatricians

Northern Territory (NT) Paediatricians are a group of specialist and general paediatricians who have worked and continue to work in the Northern Territory. We have devoted our careers to promoting the health and well-being of children and their families throughout the Northern Territory by using evidence-based practice to provide the highest standard of care.

We advocate for improvements in healthcare for the most vulnerable members of Australian society, for those without a voice. Our advocacy includes the protection of children and their families from harm caused by natural and manmade threats, including climate change and pollution.

We are not paid for our advocacy and have no conflict of interest. We are driven by the desire to provide the best medical care to our patients, support their families, and ensure that future generations can grow up in a healthy and safe environment.

The Public Health Association of Australia

The Public Health Association of Australia (PHAA) is recognised as the principal non-government organisation for public health in Australia working to promote the health and well-being of all Australians. It is the pre-eminent voice for the public's health in Australia.

The PHAA works to ensure that the public's health is improved through sustained and determined efforts of the Board, the National Office, the State and Territory Branches, the Special Interest Groups and members.

Health is a human right, a vital resource for everyday life, and key factor in sustainability. Health equity and inequity do not exist in isolation from the conditions that underpin people's health. The health status of all people is impacted by the social, cultural, political, environmental, and economic determinants of health. Specific focus on these determinants is necessary to reduce the unfair and unjust effects of conditions of living that cause poor health and disease. These determinants underpin the strategic direction of the Association.

All members of the Association are committed to better health outcomes based on these principles.

Dr Louise Woodward – Darwin Children's Clinic – PO Box 41988, Casuarina NT 0811
T: 0889017727 E: info@darwinchildrensclinic.com.au

Health Risks of Hydraulic Fracturing

The Environment Management Plan (EMP) drafted by Tamboran B2 Pty Ltd **requires a merits review on health grounds** as it does not adequately address the risks to the health and well-being of people affected by hydraulic fracturing in the Beetaloo Basin. The risk assessments provided by Tamboran class numerous sources of potential environmental contamination as "low or medium" despite **serious, potentially life-threatening, and irreversible consequences to the health of the population**. This includes a "low" risk rating to high consequence, low likelihood scenarios such as contamination of potable groundwater. An increasing body of evidence from all over the world shows **serious health impacts to people exposed to hydraulic fracturing activities, including birth defects, cancers, low birth weight, lung disease, heart disease, and an overall increase in mortality (6)**. This health research has not been considered by Tamboran B2 in their EMP and the risk rating of high consequence scenarios is unacceptably low. **The EMP proposed by Tamboran B2 is inadequate to address the health risks of all the activities proposed. A full health impact assessment is recommended.**

The EMP must demonstrate that the exploratory hydraulic fracturing outlined in the EMP will be carried out in a manner by which the environmental impact and risks of the activity will be reduced to a level that is as low as is reasonably acceptable. Based on the international evidence (6), we advise that **the fracking activities proposed will cause unacceptable risks to the health of local residents and workers, as well as the broader NT population** due to the risk of contamination of water, air, and soil by the known and unknown (commercial in confidence) toxic chemicals used in the hydraulic fracturing process, as well as contamination of the environment from chemicals brought to the surface from the shale bed (BTEX carcinogens, radioactive isotopes, heavy metals) (1). Many of these chemicals are **"forever chemicals"** such as PFAS and endocrine disrupters which can accumulate and persist in the environment as well as cause harm to humans at extremely low levels (2). Contamination of the environment by these chemicals can be irreversible and **could render aquifers for drinking unusable and animals grazing on pastoral land unsuitable to eat** (2).

To protect human health, **it is important that high consequence risks are avoided by using the "precautionary principle" where the burden of proof regarding safety rests with the proponent (Tamboran B2).** Due to the uncertainty regarding safety of hydraulic fracturing, **the activity should be paused or halted until safety can be proven. The precautionary principle is included in NT EPA guidelines and is embedded in the EPBC Act 1999, section 391** (3). Regions in North America, Latin America, Europe, South Africa, and Australia (Victoria) have banned unconventional onshore gas production on health grounds by using the "precautionary principle", and in 2012, the United Nations issued an alert on the risks of fracking to the environment and public health recommending a review of public policies worldwide (4).

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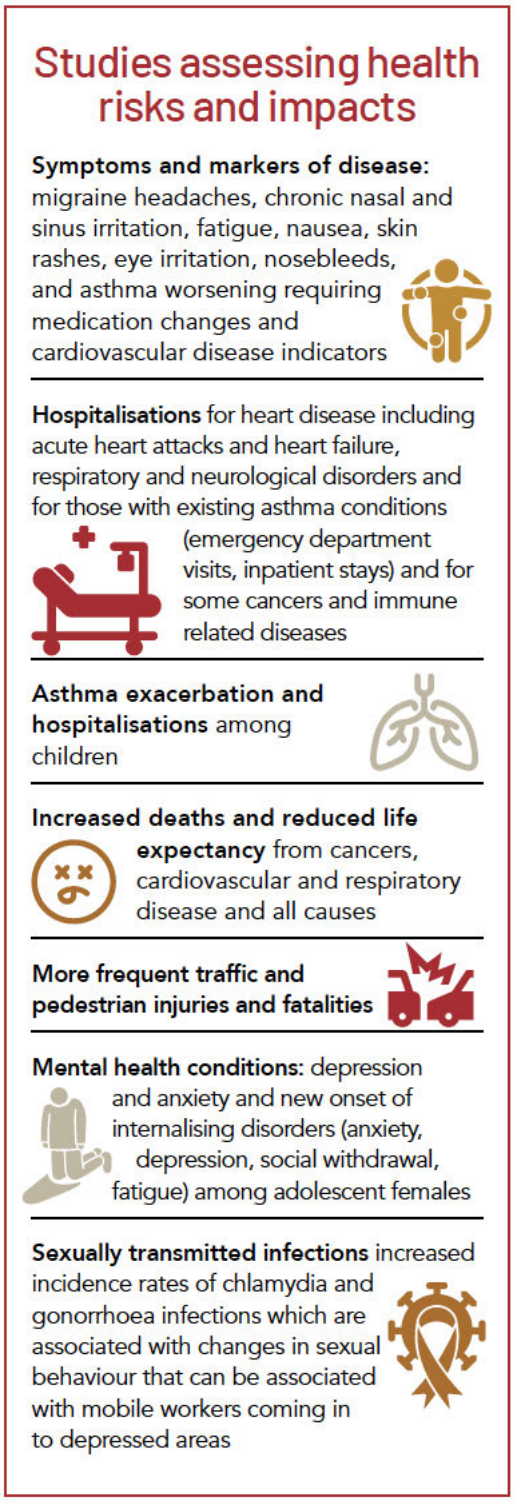
It Is alarming that some flowback water used in the fracturing process will be "recycled" for stimulation. Whilst this may reduce the volume of water used, **it increases the concentration and toxicity of the wastewater and increases the risk and consequences of environmental contamination through spills, leaks, evaporation, volatilisation, and disposal** (2).

Despite assurances of safety, the fact remains that there are several steps in the fracking process that could lead to contamination of the aquifers in this region (6). **These aquifers supply the drinking water for 90% of Territorians** (7). **Contamination can and does occur**: analysis of 1144 violation notices issued from 3533 wells in Pennsylvania found 85 instances of cement and casing failures and six cases of blowouts and gas venting between 2008 and 2011. Other violations, comprising nearly 90% of notices issued, included major and minor land spills, surface water contamination and site restoration (8,6). There is a prohibition of surface disposal of wastewater for dust suppression and other activities under NT regulations, but according to media reports, **Tamboran B2 was fined last year for using more than 300,000 litres of drilling sump wastewater for dust suppression following whistle-blower reports from workers** (5). It is violations such as this that lead to contamination of the environment and cause consequences for human health.

Regulations have not prevented many of the most serious health impacts to populations exposed to hydraulic fracturing in the USA, such as childhood leukaemia and premature death and cannot be relied upon to reduce the health impacts to local populations (9). Hydraulic fracturing requires injection of chemical containing fracking fluid into the shale bed to extract the gas, a process which also releases harmful chemicals from the shale rock, including benzene, toluene, ethylbenzene, and xylenes (BTEX) which are tightly regulated due to their toxicity and association with the increased risk of leukaemia and other blood cancers, as well as impacts on the human nervous and reproductive systems (10). Tamboran B2 assumes BTEX, phenolic compounds, and polycyclic aromatic hydrocarbon levels to be low and have placed the risk of environmental contamination as "low", despite **the CSIRO reporting that shale gas formations contain significant natural levels of these compounds and must be handled appropriately with specialist treatment and management** (11). It is difficult to assess the true concentration of BTEX, radioactive isotopes and other harmful compounds until the exploratory wells are drilled. Until accurate levels are known, it is prudent to anticipate significant levels of BTEX and other compounds in the produced water so that appropriate measures for storage and disposal can be put in place.

The use of open evaporation for wastewater as well as flowback water recycling for stimulation activities may result in increased risk of health impacts if the concentrations of BTEX and other compounds such as aluminium, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, gallium, lead, selenium, thallium, uranium, vanadium, polycyclic aromatic hydrocarbons are higher than Tamboran B2 anticipates. **Acute and chronic BTEX exposure is known to cause multiple serious health impacts via multiple exposure pathways, including contaminated soil (inhalation, skin contact, ingestion), water (ingestion, skin contact), and air (inhalation), and therefore should be given a much higher risk rating and more comprehensive management plan** (10, 11). We also know that many of the heavy metals, pollutants and volatile organic compounds found in fracking fluid and wastewater concentrate inside the bodies of adults, but particularly children (12, 13, 14).

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Haswell M, Hegedus J, Shearman D (2023). The Risks of Oil and Gas Development for Human Health and Wellbeing: A Synthesis of Evidence and Implications for Australia. Office of the Deputy Vice Chancellor (Indigenous Strategy and Services), University of Sydney

The EMP's current monitoring provisions are inadequate to safeguard community health. Scenarios such as ground water contamination must be considered and given a higher risk rating given the severe consequence. Multiple critical questions remain inadequately answered, for example: How long would it take for a leak to be detected? How many people would be left without potable water and for how long? Will Tamboran B2 supply bottled water and deliver this to residents, businesses and farms that rely on the water until the water in safe? Is the Australian taxpayer expected to pay the bill for decontaminating the water?

Harmful chemicals in the air are potentially dangerous to communities near gas and oil operations. These exposures come from drilling operations and diesel-powered machinery and trucks as well as from wastewater handling, especially when the wastewater is stored in open air ponds and holding tanks (6). BTEX chemicals, formaldehydes and acetaldehyde, hydrogen sulphide and acrolein are the chemicals likely to be of greatest concern in airborne emissions, as well as particulate matter (PM 2.5). **Air pollution from fracking operations contribute to health impacts for local populations** including **low birth weight, pre-term birth, asthma exacerbations, childhood leukaemia, heart disease, headaches and migraines, sinus disease, respiratory disease, a variety of cancers, mental health conditions, and excess mortality** (6).

Indirect Health Impacts of Hydraulic Fracturing

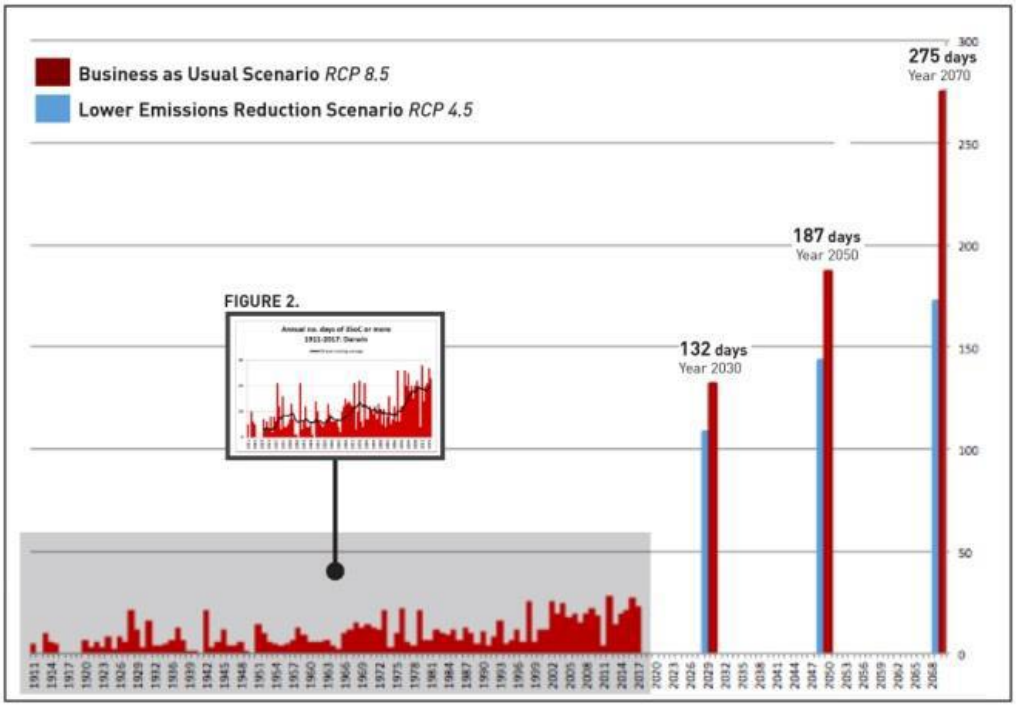
The already strained health system in Katherine, Tennant Creek and the surrounding remote health services are not resourced to manage an increased burden of disease due to shale gas hydraulic fracturing in the Beetaloo basin. Healthcare costs are much higher in the NT due to small, remote, and widely dispersed populations, and many specialist services are unavailable. **There is no paediatric oncology service in Darwin or Alice Springs**, so any increased cases of cancer must be evacuated interstate at great cost to the family and to the taxpayer. **There is no neonatal intensive care unit in Katherine or Tennant Creek**, so any pre-term babies must be evacuated to Darwin, causing great strain on families and the emergency retrieval service. The intensive care units in Darwin and Alice Springs manage children with severe asthma but it is not a specialist paediatric ICU, making the management of more severe or complex asthma exacerbations in children more difficult and burdensome for the limited ICU resources. **Increasing the burden of disease due to chemical contamination of the environment from hydraulic fracturing, even in the exploratory stages will cause unnecessary strain on the Northern Territory health system**.

The project proposes to offset carbon emissions over 100 000 tonnes in any financial year as required under DCCEEW. **We draw attention to serious concerns with Australia's offsetting mechanisms** (24). Regardless of whether these upstream emissions during gas production can be offset, they comprise only an estimated 20% of the total greenhouse gas emissions of the project, with the majority of being carbon dioxide from utilisation of the gas (25). Scope 1,2, and 3 (all-scope) emissions contribute to climate change and all need to be considered in the context of addressing the climate crisis.

The all-scope lifecycle greenhouse gas emissions of the Beetaloo basin gas project will intensify climate-related harms. Climate change is predicted to increase the rates of injury and disease both for Territorians and the Australian population more broadly (18). However, the health impacts of climate change will be felt inequitably. Individuals and households with low income, people with a disability and chronic disease, the elderly, and children are disproportionately impacted as they are physiologically more vulnerable, and less able to escape climate related hazards such as heat and extreme weather (19). This should be of particular concern, given that many people in these population groups in the NT already experience a greater avoidable burden of disease compared with the rest of the population (20).

The number of extremely hot **(high heat stress) days in Darwin will increase** dramatically in the coming decades under CSIRO climate modelling. Under a business-as-usual scenario on greenhouse emissions, **the CSIRO estimates Darwin could experience days 132 days over 35oC per year in 2030, 187 days per year by 2050 and 275 days per year in 2070 (28).**

Darwin days over 35oC per year historic and CSIRO future modelling



Hanna E, Ogge M. Cooked with Gas, extreme heat in Darwin. March 2018, The Australia Institute.

Climate change will make rainfall in the NT more variable, with greater fluctuations between wetter and drier conditions (21). This increases the risk of food insecurity due to disruptions to the food supply chain, especially in economically disadvantaged and rural and remote communities in the Beetaloo basin (22). **There is an increased risk of flooding, which increases the risk of environmental contamination from fracking wells and storage ponds, as well as the risk of people being displace, resulting in poor mental health and an increased risk of injury** (21). There is an increased risk of potentially fatal vector-borne diseases such as malaria, dengue, Japanese Encephalitis and Murry Valley Encephalitis with increasing temperatures and humidity, placing even greater burden on vulnerable communities (23).

Dr Louise Woodward – Darwin Children's Clinic – PO Box 41988, Casuarina NT 0811
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Conclusion

When the consequences of environmental contamination from fracking (exploration and production) are high or irreversible, **the precautionary principle should be applied, and hydraulic fracturing should not be permitted to proceed any further**.

The health impacts of the hydraulic fracturing are now well documented and researched. Ever more robust evidence is demonstrating the devastating health impacts of hydraulic fracturing. This evidence can no longer be ignored. **A comprehensive health impact assessment (HIA) into hydraulic fracturing should be undertaken with robust methodology approved by a panel of independent public health experts**. The HIA should be done prior to granting any more exploration licences for onshore hydraulic fracturing.

Climate change is a health issue and must be taken seriously, particularly in the Northern Territory which is already experiencing dangerous global heating. Shale gas extraction and burning are major contributors to greenhouse gas emissions and climate change. The expansion of the gas industry in the Beetaloo basin is a major environmental and economic risk during a climate crisis and energy transition. **Carbon offsetting, even for emissions during production, has been discredited and should not be relied on.**

The health and well-being of Northern Territorians must be prioritised and protected from the onshore gas industry which has a history of environmental contamination with devasting health impacts for local populations, despite robust regulations. **A merits review of the Tamboran B2 EMP is strongly recommended by the Public Health Association of Australia and the NT Paediatricians** who service the Beetaloo region and provide specialist advice to health professionals throughout the Northern Territory.

Dr Louise Woodward – Darwin Children's Clinic – PO Box 41988, Casuarina NT 0811
T: 0889017727 E: info@darwinchildrensclinic.com.au

References:

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[redacted]

From: AP4CA NT <ap4ca.nt@gmail.com>
Sent: Thursday, 14 December 2023 7:13 AM
To: tamboran DEPWS
Cc: Onshoregas DEPWS
Subject: Submission on Tamboran Shenandoah EMP
Attachments: Tamboran Shenandoah EMP Submission.docx

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Please accept the attached submission on behalf of our group. Unfortunately the portal for uploading submissions seems to have closed prior to the 12pm deadline and so we are emailing directly instead, we trust this is acceptable.

Kind regards,

Parents 4 Climate Darwin & NT

PARENTS FOR CLIMATE



Parents for Climate Darwin and NT Submission in response to:
Tamboran Resources Ltd Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98

This submission is made by Parents for Climate Darwin and NT. We are a local grassroots group made up of volunteers and we are members of the national Parents for Climate (PFC) not for profit.

Our group represents hundreds of families in the Northern Territory (NT) and we are united by our pressing concern about climate change and the harmful impacts it will have on young people in the NT now and into the future as they grow up in a hotter and more dangerous climate. Our group is dedicated to advocating for a safe and healthy environment and climate for our kids and young people. As parents and carers we have an innate responsibility to ensure the health and safety of our children, this is what motivates us to give up countless volunteer hours for the cause.

In the first instance we would like to express our disappointment in relation to the timing of the release of this EMP which has meant the window of opportunity for comment has fallen squarely within the Christmas holiday period when families are busy and have limited capacity to engage in the process. This has the affect of excluding families from engaging and commenting on the E&A programme EMP, which we argue will have significant environmental impacts. Some might interpret the inconvenient timing of Tamboran's EMP submission and the subsequent release as a deliberate decision to try and dissuade community engagement. Whether true or not the perception may permeate among the public. We suggest the period for community comment should be extended by another two weeks to allow for a greater level community engagement and participation.

Given the short time frame for comment and the fact that it fell over the busy Christmas holiday period, our group has not been able to dedicate the attention required to submit a comprehensive response to this lengthy EMP, which is unfortunate. Should the department decide to extend the comment period we would seek to resubmit a fuller response. In the meantime we submit the following comments.

The activities covered in the Shenandoah EMP have the potential to significantly impact the environment in a multitude of ways, including:

- **negative impacts to water quality in the region which could extend well beyond the primary sites of activity;**
- **negative impacts to water quantity through ground water draw down which could impact iconic and culturally significant NT water sites such as the Roper river, Mataranka hot springs and Lake Woods wetland; and**
- **the outlined activities in this EMP – as well as activities that will ensue in the future as a consequence of this exploration and appraisal stage – will drive unacceptable and harmful increases NT GHG emissions.**

Given the activities covered by this EMP is a first step along a path that will likely lead to fossil fuel gas production and sale across Tamboran's lease hold areas, it is critical that the cumulative impacts of Tamboran Resource's larger agenda should be considered as part of this EMP proposal.

Furthermore, given the steep increase in commercial activity across a range of sectors within the Beetaloo region the cumulative impacts of all sector activities should be considered to ensure proper environmental protections. Even more so given the connectivity between aquifers and basins. And the cumulative emissions load that would be generated across all industry activity in the area, and the impact that will have on the NT's ability to meet a net zero by 2050 target.

In relation to risks of significant environmental impact, the points we wish to forefront are:

- **Under the EMP activities it is proposed that 1.5 billion litres of water will be extracted over 4 years. The EMP fails to**

adequately demonstrate how possible significant impacts to ground water will be mitigated.

- **There are critical knowledge gaps in relation to inter-basin and inter-aquifer flows[1]. A precautionary approach should be taken when approving projects that include extraction of significant volumes of water.**
- **We are concerned the GHG emissions estimates for activities covered by this EMP are underestimated and require further scrutiny.**
- **Even by the carbon accounting laid out in the EMP and solely covering the activities there within, the estimated emissions are almost half a million tCO2e. This is significant even without taking into account cumulative emissions from Tamboran Resources full fossil fuel gas extraction agenda.**
- **Once Tamboran Resources are fully operational Tamboran claims their LNG plant will produce 20mtpa, which will generate well over 1 billion tonnes C02e over a 20 year period[2]. This will have a significant impact on Australia's ability to meet a net zero by 2050 target and the emissions contribution will further warm the planet and impact NT environmental values in an indirect way.**
- **To be compatible with recommendation 9.8 of the Pepper Inquiry all lifecycle emission produced in Australia must be offset. This EMP does not outline how this will be done.**
- **To be compatible with the Safeguard Mechanism all scope 1 emissions must be offset and Tamboran Resources has not sufficiently demonstrated how those emissions will be offset or from where they will secure carbon credits.**

Given the risk of significant environmental impacts as a result of the proposed activities, the *Environmental Protection Act* applies and the following action should be taken:

1. **the Shenandoah EMP should be referred to the NTEPA;**
2. **the Shenandoah application should not be considered until the EMP is referred to NTEPA and a decision is made in**

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[1] Matthew Currell and Christopher Ndehedehe, Griffith University, The Cambrian Limestone Aquifer, Northern Territory: Review of the Hydrogeology and Management Rules to Ensure Protection of Ground Water Dependent Values, 2022.

[2] Mark Ogge, Australia Institute, Emissions from the Tamboran LNG facility https://australiainstitute.org.au/report/emissions-from-the-tamboran-nt-lng-facility/

accordance with Environmental Protection Act legislation; and

3. **the project should be referred under the *Environment Protection Biodiversity Conservation Act 1999* to be assessed in relation to its potential to cause significant impacts to matters of national environmental significance.**
4. **an across the board two week extension on the deadline for submissions on the EMP should be granted to ensure greater opportunity for community participation in the process.**

With thanks and kind Regards,

Parents for Climate - Darwin and NT

[redacted]

From: Jorgen Asmussen Doyle <jorgendoyle@gmail.com>
Sent: Monday, 8 January 2024 3:06 PM
To: tamboran DEPWS
Subject: Submission re EP98 & 117
Attachments: CAFFA submission EP 98 & 117.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To whom it may concern,

Find attached the Central Australian Frack Free Alliance's submission regarding Tamboran Resources' proposed work program on EP98 & EP117.

Kind regards,

Jorgen Doyle
on behalf of the Central Australian Frack Free Alliance

8 January 2024

DEPWS Petroleum Operations Unit,
Northern Territory Government
By email: TAM1.EP98+117@nt.gov.au

SUBMISSION - Tamboran Beetaloo Basin Shenandoah South E&A Program (TAM1-1)

The Central Australian Frack Free Alliance (CAFFA) welcomes the opportunity to comment on the Environment Management Plan submitted by Tamboran for its proposed works program on the Shenandoah South site; EP117 & EP98 ('the EMP').

Acknowledgement of Country:

The land where the Central Australian Frack Free Alliance (CAFFA) is based is the unceded sovereign Country of the (Central) Arrernte people. We acknowledge the Arrernte people as the Traditional Owners and Custodians of Mparntwe/Alice Springs and ongoing resilience and resistance in the face of colonialism.

We stand with Traditional Owners and Custodians in the Northern Territory and beyond who seek to protect their Country and water from fracking. We support the self-determination of First Nations people everywhere.

About us:

The Central Australian Frack Free Alliance (CAFFA) is a grassroots community group located in Mparntwe/ Alice Springs organising to protect the NT's water, health, communities and country from the harms of unconventional gas extraction. We have been active over the last nine years in raising awareness within the Central Australian community about the risks posed by this poorly regulated and inherently dangerous industry. The Central Australian Frack Free Alliance opposes fracking and all new fossil fuel projects in the Northern Territory.

Our work has seen CAFFA engaging with the community through market stalls, letterboxing, community surveying and other social events. In taking action, CAFFA stands alongside Traditional Custodians who are fighting to protect water, country and culture. We take our mandate from the people of Alice Springs: 80% stated they do not want fracking in a December 2022 survey, with just 5% in favour.

To build community capacity for opposition to new fossil fuel extraction, CAFFA undertakes a range of activities including:

● Awareness raising: Raising awareness of the risks of fracking through education, media and social media engagement.

● Research: Undertaking qualitative and quantitative research to capture community perspectives and concerns.

● Resource development: community education on the risks of fracking, fossil fuels and the climate crisis.

● Community engagement: Organising and participating in community events and contributing to local life in Mparntwe/Alice Springs.

● Alliance building and solidarity: Establishing new partnerships, contributing to relationships with other groups and networking in local, regional and national contexts to achieve our aims and stand in solidarity with others.

● Policy advocacy: Supporting changes to legislation and policy that promote First Nations sovereignty, oppose new fossil fuel extraction, and protect the environment.

● Direct action: Engaging in direct action in order to oppose all new gas/fossil fuel projects in the Northern Territory, guided by the principles outlined below and our Code of Conduct for Direct Action.

Our Objections:

Serious deficiencies in community consultation

There have been serious deficiencies in community consultation for this proposal. Statutory timeframes constrain the discretion of the Minister and Department from allowing the public and affected communities, including Traditional Owners and Native Title Holders, a reasonable opportunity to read, respond and engage with over 3,600 pages of material during only 28 calendar days covering Christmas and New Year.

The timing (Christmas/New Year holiday season) of the release for public comment of Tamboran Resources Ltd's EMP amounts to a willful tactic to avoid public scrutiny on the part of proponent. This tactic further erodes public trust and confidence in the company's commitment to transparency and accountability, and responsibility in fracking for fossil methane gas in the Beetaloo sub-basin.

The proponent's record of operating in the region casts doubt on its ability to reduce environmental impacts to as low as reasonably practicable (ALARP)

The EMP fails to meet approval criteria to reduce risks to as low as reasonably practicable (ALARP) or to a level that is acceptable in, for example, the management of fracking wastewater and the management of greenhouse gas emissions, as detailed in the submission.

There are several instances where the requirements of the Code of Practice: Onshore Petroleum Activities in the Northern Territory (the Code of Practice) are not met, particularly with respect to:

● the discharge of wastewater and the use of open storages of wastewater;

● the requirement for six months of baseline data to be established from groundwater monitoring bores prior to drilling commencing;

● the requirement for “an auditable chain of custody system” for wastewater tracking; and

● the requirement for the EMP to include, where onsite disposal of drill cuttings is proposed; “certification from a suitably qualified third party that the material is of acceptable quality for disposal to land by the proposed method.”

Tamboran’s recent activities in the region is a relevant consideration for this EMP and the proponent’s ability and commitment to reducing impacts to as low as reasonably practicable. In January, 2023 Tamboran was issued a $6500 by the Territory’s petroleum regulations unit for an environmental breach involving the intentional pouring of over 300,000 litres of drilling sump water onto the ground on the site of its drilling operations (Tanumbirini 2H) on Tanumbirini Station to act as a dust suppressant.

Following investigations commissioned by the pastoral station on which the Tanumbirini 2H well is sited and undertaken by independent water ecologist Dr Ian Wright, the Territory’s petroleum regulations unit is undertaking two further investigations, the status of which is currently unknown. The two investigations currently underway involve:

1.) a bund wall breaking and spilling sediment and potentially toxic chemicals down towards a sacred waterway and;
2.) what appears to be the pumping of toxic wastewater, containing heavy metals including lead and barium, which is highly toxic to humans, stock, wildlife and the environment, into a cattle breeding paddock.

The EMP relies on the Pepper Inquiry recommendations being implemented in full to support its claim to have reduced environmental impacts ALARP

Furthermore, the proponent relies on the Code of Practice and the Fracking Inquiry recommendations for its claim to have reduced impacts to an acceptable or ALARP level, despite several crucial recommendations from that Inquiry remaining unmet. Given that the necessary precondition that “all of the recommendations made in [that] Report are adopted and implemented in their entirety” is not met, this test for acceptability of the risks associated with an onshore gas industry is also not met.

Recommendations still outstanding from the Pepper Inquiry include:

● Recommendation 7.12: Requirement that enclosed tanks must be used to hold all wastewater. We note that this EMP includes extensive use of evaporation ponds as a wastewater management tool.

● Recommendation 7.17: Discharge of any wastewater to be prohibited. Despite the prohibition created in the Water Act 1992, we note that this EMP proposes that the operation will include the discharge of wastewater.

● Recommendation 9.8: That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT. The direct greenhouse gas emissions resulting from this

project will increase NT's emissions by more than 3.4% and full lifecycle emissions in Australia have not been estimated.

● Recommendation 7.15: Gas companies must submit details of the locations of all faults that could compromise well integrity. There is limited mention of faulting in the EMP and the risk that encountering faults poses to groundwater.

The EMP does not pay adequate attention to the cumulative risks of the proposed activities

The EMP continues the time-worn tradition maintained by proponents of fracking proposals in the NT of entirely disregarding the requirement to assess "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity" as required by Sch 1, s 3(2)(b) of the PERegulations. The proponent makes no attempt to describe the cumulative climate impacts of exploration and production activities on the environment in which this fracking is proposed to take place, nor is there cumulative impact assessment of impacts on biodiversity and groundwater, beyond mere addition of tonnes of greenhouse emissions, hectares to be cleared and volumes of water to be extracted, none of which describe the "effects" of these impacts.

The EMP further fails to assess "the cumulative effects of those impacts and risks when considered with each other and in conjunction with any other activities or events that occurred or may occur in or near the permit area for the regulated activity" as required by Sch 1, s 3(2)(b), because:

● The recent and anticipated emissions from other proponents' gas appraisal activities in the Beetaloo and broader McArthur Basin area are not included in the cumulative emissions assessment;

● The clearly foreseeable scope 1 emissions impact of the construction of infrastructure required to support a shale gas industry in the Beetaloo – the end goal of Tamboran's exploration and appraisal program – is not included in the cumulative emissions assessment; and

● The clearly foreseeable scope 3 emissions impact of the combustion of gas sold from Tamboran's anticipated production of onshore gas in the Beetaloo is not included in the cumulative emissions assessment.

Obfuscation and underestimation of greenhouse gas emissions of the activities proposed

Tamboran uses various accounting (and discounting) techniques to confuse and understate the emissions from this project. A proposed and undescribed "flare avoidance program" has been used to substantially – and misleadingly – lower projected emissions for FY2026 and FY2027, despite that program still being deeply uncertain and subject to Native Title consent, regulatory approval and the proponent's own unmade decision to expend "$10's of millions" on appraisal sale infrastructure. **Given the flare avoidance program is not described or committed to in the EMP, the regulator must assess the proposal based on the actual emissions it will create, which represent a significant impact on the environment and people of the NT.**

The EMP further states that beneficial use of gas is not part of the current proposal, yet goes on to assume beneficial use of the gas recovered from 2025 onwards in order to reduce direct emissions below

the Safeguard Mechanism threshold after 2025. The proponent's estimate of 400,000 tonnes CO2-e over the four years of the works program therefore cannot be relied upon.

Based on information provided elsewhere in the EMP, the emissions outcome is much more substantial:

FY24: Based on Figure 5 (p42) setting out the timing of activities, FY24 has no fracking and well testing activity, just well drilling (2 wells). The stated emissions (table 23) are 24,662 tCO2-e.

FY25: Based on Figure 5 (p42), FY25 has 3 wells scheduled for fracking and testing/flaring. The stated emissions are 190,838 tCO2-e.

If three wells fracked and tested/flared produce 190,838 tCO2-e then 15 wells as proposed would be expected to produce a total of ~954,000 tCO2-e.

~954,000 tCO2-e is more than double the total emissions stated by Tamboran in the EMP.

The EMP grossly understates the emissions from this project. Consequently, all the EMP's subsequent misinformation about offsets, net zero, Safeguard Mechanism implications, etc, cannot be relied upon.

Even if the proponent's estimate of 400,000tCO2-e emissions generated over four years could be regarded as plausible, the project is still subject to the Territory's major emitters policy, yet no mention of the policy is made in the EMP. The major emitters policy applies to "all new projects and expanding existing projects likely to be large emitters that occur after commencement of this policy and which are required to obtain an environmental authorisation under Territory legislation to proceed." The threshold for the major emitters policy is similar to the Safeguard Mechanism: Estimated scope 1 emissions of 100,000tCO 2-e in any financial year over the life cycle of a project, not counting emissions generated from land clearing directly associated with the project. The major emitters policy requires proponents to develop and implement a greenhouse gas abatement plan (GGAP) that has been tailored specifically for their project. No such plan has been provided.

Climate impacts of the proposed activity contrary to the principles of ecologically sustainable development

The proponent's EMP has failed to meet the approval criteria in section 9 of the Petroleum (Environment) Regulation 2016 (PER) on a number of counts, including:

● It provides incomplete and inaccurate information about its emissions of greenhouse gases. The estimate of 400,000 tonnes of greenhouse emissions over four years cannot be relied upon by the decision-maker in assessing this application because it relies on a "flare avoidance program" that is not part of this EMP application and may be determined by the proponent to be too expensive to pursue. In its third year of operation, emissions could be as high as 490,575 tonnes, increasing the Territory's annual emissions by **3.4%.**

● Furthermore, the proponent's emissions estimates from flaring relies on outdated methods and may be under-estimated.

● The proponent invokes lifecycle greenhouse emissions benefits of gas as a replacement for

coal power in undisclosed locations, but does not include assessment of lifecycle emissions from the project, including emissions from sand mining for proppant, transportation to Queensland of waste materials, and downstream use of the gas if beneficial use is pursued.

● The proponent relies on the tired and scientifically bereft argument that gas that may be extracted in commercial quantities as a result of the exploration and appraisal activities contained in this EMP will replace coal fired power in undisclosed locations, thereby resulting in a net climate benefit. This position is severely imperilled by facts, including the following:

a. A new study by one of the world's premier methane scientists finds that gas may be 24 percent worse for the climate than coal in the best-case scenario, thanks to extensive methane leaks at just about every stage of its production, from drilling to transportation. In the worst-case scenario—when LNG makes long journeys on old, polluting tankards—the fuel is 274 percent worse for the environment than coal is.
b. This peer-reviewed academic article published in the journal Nature Energy in 2022 argues that the expansion of natural gas infrastructure hinders a renewable energy future and the natural gas 'bridge' narrative is misleading; that the climate impact of natural gas has previously been underestimated and that new insights about this are not sufficiently incorporated into energy analyses; and that investments in natural gas make it harder to achieve climate targets due to lock-ins, and carry high economic risks.
c. In 2019, Woodside commissioned the CSIRO to undertake research to support its claim that gas from its Scarborough project would displace coal use in Asia (the precise claim Tamboran makes). The report is entitled "Modelling the emission impact of additional LNG in Asia". The report was quietly shelved by Woodside after it concluded that increasing Australian gas supply could prolong coal, displace renewables and increase emissions in Asia without a global carbon price.

Tamboran concedes in its EMP that "exploration activities are an essential step in defining a potential future commercial resource" (section 2.1). While willing to claim the purportedly "sustainable, long-term benefits to the local community, to the Barkly region generally and more broadly into the rest of the NT," (page 35) of the full-scale production for which this project is "essential," the EMP does not engage with the profound inter-generational inequity resulting from the climate change implications of exploiting this resource. To address all the environmental risks and impacts arising indirectly from all aspects of the activity and the cumulative effects of those impacts and risks that may occur, requires the proponent to describe the global warming scenario that is consistent with its plans for full scale gas production and the effects of that warming on the environment of the NT.

We note that under s 24(3) of the EP Act, the ecologically sustainable development principle of improved valuation is described as including, for the purposes of Territory law "Users of goods and services should pay prices based on the full life cycle costs of providing the goods and services, including costs relating to the use of natural resources and the ultimate disposal of wastes." Tamboran has made no attempt to describe or estimate the full life cycle costs of providing the gas it proposes to extract under this EMP, nor the cost of disposal into the atmosphere of escaping methane and other greenhouse gas emissions.

There is considerable evidence available that global average temperature rise is near to passing the threshold of 1.5 degrees above pre-industrial levels, and institutions such as the International Energy

Agency (IEA) have concluded that to prevent this threshold being breached, there is no room for new gas production anywhere in the world.

Inadequate and non-compliant measures to protect water resources

The EMP envisages 2 x 8.5km “gathering networks” above and below ground for wastewater *and hydrocarbon* transportation and storage. This is a high risk proposal that has been described within the EMP in highly opaque terms and cannot be approved. This is the first time such a network of plastic pipes carrying toxic and hazardous materials has been proposed in the Beetaloo and it raises serious issues that have been ignored or downplayed in the EMP. This includes the risk of methane leakage, the risk of fire or explosion and the risk of contaminated wastewater leakage resulting in pollution of streams and wetlands. The proponent acknowledges in the EMP (p 62) that the employment of the gathering network is at least partially intended as a cost-cutting measure, betraying Tamboran’s willingness to gamble with the environment in order to reduce costs. This is not consistent with the requirement under the Code (section C.4.1.2) to reduce environmental risks ALARP.

The Water Act 1992 prohibits fracking wastewater releases to surface water bodies under section 17A. The EMP claims in its summary that “No wastewater release to surface water proposed” (Table 8) but elsewhere contemplates “Most of the water will be re-used, with any unused groundwater released through a controlled discharge to the area surrounding the lease pad” (page 83). As detailed above, non-compliant and allegedly deliberate releases of wastewater have already occurred at sites operated by this proponent and arrangements are not in place to confidently prevent this again. Given the operation is upstream of the internationally significant wetland, Lake Woods, the proponent’s history of spills and improper handling procedures is relevant to the decision being made about this EMP.

The Code of Practice at section C.4.2.2 lists mandatory requirements for produced water and flowback fluid, including that **“All produced water and flowback fluid must be held in above-ground enclosed tanks at all times following release from the petroleum well”** unless in specifically listed circumstances, including being treated for reuse or disposal. The EMP does not achieve this mandatory requirement, and expressly proposes the holding of large volumes of wastewater in open ponds and tanks for the purposes of evaporation. The EMP describes evaporation as a “treatment” process (page 92) but the process of evaporation is in fact the opposite of treatment - concentrating pollutants that are held in the environment, according to the proponent’s plans, in open storages, vulnerable to leaks, spills and floods. The evaporation process concentrates contaminants from drilling fluids and flowback and produced water, including potentially radionucleides, which may, once dried, become mobilised by wind.

Given its proximity to Lake Woods and nearby waterholes on Newcastle Creek, where 7000 records of 81 waterbird species were collated in the SREBA report, these open wastewater ponds pose a significant and unacceptable threat to biodiversity.

The EMP makes the alarming admission that in the previous drilling of the Kyalla-117 N2-1 E&A well, it appears that there may have been “total loss” of drilling fluid, including its chemicals, into the productive aquifer that is relied upon by water users in the region:

> *The limestone in the CLA is commonly fractured and cavernous; in the Katherine region, bore yields of up to 100 L/s have been recorded from this aquifer (SREBA, 2023). Such high yielding sections were encountered when drilling the Kyalla 117 N2-1 E&A well through*

the Anthony Lagoon and Gum Ridge Formation, with total losses of drilling fluid circulation at specific intervals. (page 155)

This is a further risk that remains undescribed in the EMP and belies the proponent's claims to have reduced risks to water resources ALARP. This is a particularly acute risk given that the proponent proposes to drill through seven (7) aquifers in order to access the target 'Velkerrie' formation (table 35, p154).

Based on the table provided (Table 6, '3 well totals') the 15-well project would entail the transport, storage and pumping down-well of a total of ~10,000,000 litres/kilograms of fracking chemicals (excluding sand/proppant). At least 33 of the chemicals could be 'high concern' due to potential toxicity. One of the compounds listed in the table with a letter code "BE-9 biocide" has been identified as Tributyl tetradecyl phosphonium chloride – a compound with very high acute toxicity, and for which biodegradation information is currently not available. Based on figures provided in the EMP, including the stated "15% recovery of fracking fluid" (p109), the project would involve the generation, storage, movement and disposal of over 180 million litres of contaminated wastewater (22.5 ML drilling fluids; 162 ML recovered fracking fluids). If as stated only 15% of chemical-laced frack fluid is recovered per well, this means 0.85 x 10,000,000 = 8,500,000 litres/kilograms of fracking chemicals, many of them toxic, will remain underground in fractured geological formations.

Unexplained increase in groundwater use for fracking

In previous EMPs for operations in this region, targeting the same formation, water use for fracking per well has been given as around 25-45 ML. Under this EMP, the proponent is proposing to extract and use **2.5 ML per E&A well** for drilling and completions, and **72.0 ML per well for stimulation.** No explanation is provided for this 150-270% increase in groundwater use per well. Given that, according to the EMP, only ~15% of fracking fluid is likely to be recovered, the company cannot claim that reuse or recycling of fracking fluid is likely to result in significant reductions in total water use for fracking. The direct, indirect and cumulative impacts of this massive increase in water demand have not been presented or considered in this EMP. This is a clear breach of the relevant legislation and regulations.

Tamboran's environmental track record

Section 6(1)(d) of Schedule 1 of the PERegulation requires that the Implementation Strategy of an EMP includes "monitoring, recording, audit and management of non-conformance with the plan and review of the interest holder's environmental performance." The recent history of the proponent in the region suggests there are reasons to doubt its ability and willingness to meet its environmental obligations under the regulations.

Recordable and reportable incidents occurring on Tamboran sites in the last eighteen months include:

- Holes discovered in the liner of a tank being used to store waste solids, resulting in a spill to the hardstand;
- A spill of 3,520 litres of drilling mud to the ground because of poor condition of hoses;
- A spill of 800L of flowback water as a result of another leaking linter in a wastewater tank;
- A spill of 1000L of sodium bromide while site bunding was out of service;
- Alleged pumping of contaminated water from the "Maverick 1" well site onto Tanumbirini Station;

● Failure of bunding at the Maverick 1 site during a heavy rainfall event;
● An estimated 314,600L of low EC drilling wastewater estimated to have been utilised for dust suppression in order to lower fluid levels in a tank above the wet season freeboard level.

Given this history of incidents relating to handling, oversight and spill prevention, there is good cause to doubt the proponent's willingness and ability to reduce the environmental risks of the proposed activities to as low as reasonably practicable.

Code of Practice: Onshore Petroleum Activities in the Northern Territory (2019)

Based on the information provided, there are several areas where the requirements of the Code of Practice are not met:

● the discharge of wastewater and the use of open storages of wastewater;
● the requirement for six months of baseline data to be established from groundwater monitoring bores prior to drilling commencing;
● the requirement for "an auditable chain of custody system" for wastewater tracking, and,
● the requirement for the EMP to include, where onsite disposal of drill cuttings is proposed, "certification from a suitably qualified third party that the material is of acceptable quality for disposal to land by the proposed method."

Referral to the NT EPA required

This proposal has not been submitted to the EPA for assessment by the proponent itself. You, as the relevant decision maker, have the power to refuse to consider the application until the action is referred to the NT EPA and a decision is made on referral.

The proponent, in its EMP states claims: "Tamboran has completed a self-assessment. The level of potential environmental impact is not considered significant." Given the scale and magnitude of the regulated activities being proposed, including land clearing, exploration through fracking, penetration of important regional aquifers with the potential for inter-aquifer connection should well barriers fail, complex wastewater management systems and hazardous chemicals handling, CAFFA submits that the Department must refer this activity to the EPA as per s50 of the Environment Protection Act 2019 Each of these activities have the potential to cause a significant impact to the environment and are thus required to be referred to the EPA for assessment under the Environment Protection Act 2019.

Conclusion

For the reasons set out above, CAFFA objects to this exploration and appraisal program. CAFFA submits that the EMP does not comply with legislative requirements for the approval of an Environmental Management Plan and, based on the incomplete and inadequate information provided, is environmentally unsustainable and unacceptable. Therefore the Minister is obliged to reject the EMP and the project.

Sincerely,

The Central Australian Frack Free Alliance
Mparntwe/ Alice Springs, January 8, 2024

[redacted]

From: Protect Big Rivers <protectbigrivers@gmail.com>
Sent: Tuesday, 9 January 2024 6:20 PM
To: tamboran DEPWS; Onshoregas DEPWS
Subject: Submission
Attachments: Ray Dixon EMP.docx

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

Please find attached Submission for EP 117 & 98 from
Ray Dimakarri Dixon.
Marlinja Native Title Holder.
Ray is happy for his details to be published.
I have lost Ray's email address in the confusion of the portal closing early today however you can contact him on 0467244974 to obtain.
Regards,
Sam Phelan
Secretary Protect BIg Rivers

My name is Ray Dimakarri Dixon. I am a Mudburra man from Marlinja Community. I speak for water. I live downstream from the Beetaloo Basin. I have been saying this for 10 years now. I have told Origin Energy that they should not be mining in the area as we are connected to that water. Water flows from the Northeast of us, it comes down to my grandfathers and my mother's country. It goes straight down to Lake Woods.

The water carries songline for us. It is sacred to us. We need to introduce strangers to our land in a cultural way and we use water for this. That is why we don't want the mining mob to destroy our water. It is so valuable to us through our connection to it.

The mining companies are not communicating in a true way with traditional owners from this region. They do not talk to us about how much water they will be using for this fracking. Most of the TOs do not understand what a megalitre is or how much water will really be used. That is the scary bit. They are not communicating properly with traditional owners. They are not telling owners what chemicals they will be using to frack the land.

We only get big water from rain here. It only comes every year, not every week or month. We get one off big rain here. Everyone here depends on the aquifer for nearly the whole year. We worry that by fracking we will damage the aquifer, and that the directions of underground flow might change. I would like the mining companies and the government to take these risks seriously. We have lived on this country for thousands and thousands of years, the mining companies and the government don't live here.

We protect country using ceremony. Any damage to our aquifer is culturally devastating. When we sing song, we don't want that song to go into dirty water with chemical in it. That is the biggest threat to us. The Government need to take this really seriously. It is for our future. We want the next generations to live on their own homelands, with their own tribe, on country they call home; where they can hunt and use bush medicine.

Tamboran, in late 2022, were working North of Newcastle Creek. They were drilling there. They were drilling where the creek bed comes through from the North and flows into the main Newcastle Creek. It flows though my grandfather's country when big wets come. We had a good wet season that year. It filled up their waste pond. Tamboran mob were wondering what to do with all the waste. They sprayed it out where it could reach the creek bed. My people don't know what chemical got into the creek bed, but we know that anything to do with chemicals is toxic. No one from Tamboran or the government has ever been to our community to talk about this.

That contamination is the first risk there. Why are they asking for 19 more wells in an area that they have already been acting so blindly in. For sure the chemical is there on the ground, in the trees, or in the creek bed, waiting for a big flood to come. When the water comes from that flood it will push it all the way down to where my family live and into Lake Woods. This is the last beautiful thing we have. Tamboran and the Government cannot replace this. They won't give us back our Lake or our creek bed.

We get fish, turtle from the water. Kangaroo and goanna, turkey, porcupine all drink this water too. This water is also a refuge for migrating animals like magpie geese. They spend

the hot time of the year in the floodplain. We have been drinking that water for over 60,000 years on this land. The government is not going to replace that for us if it is contaminated.

In 1974 I was only 10 years old. I can remember where I was on Newcastle Station with my mum and dad who were working there. It was holiday time. All work had stopped. There were rumours going around that a big wind was coming from Darwin and that Darwin was going to get wiped out, and it did.

Through that '74 the rain was hammering the whole of the Northern Territory. We were staying in one of the old working huts on Newcastle Creek. The water was through all the black soil country. The rain came day and night for days and days, maybe a week or more. We were cut off. The station was underwater. The water came around to the homestead and it was underwater too. We couldn't get anywhere for over a month and a half. We didn't care, we were on country and at home and happy. We were fishing and hunting. Where Marlinja is now was like a little Island. The horses came up there. Everywhere else was covered in water.

The '74 flood was fast. The landscape filled and flushed through the creek beds. Nothing could hold it back. It rained day and night for 2-3 weeks, constantly. We've had a few good wets since then but nothing that compared to 1974. 1974 was different. The amount of water dumped where they are planning to frack was huge. The Lake filled and when that Lake fills it pushes the water back upstream. The water also goes around through Beetaloo Station and the water from the Barkly area comes back this way too. The whole landscape was covered in water. All the Lakes join up, all the water eventually comes to the Newcastle Creek channel and into Lake Wood. So, whatever they do up on the fracking leases will come this way.

Looking at the map I know this mining is happening in the flood zone. It is on a floodplain. It is a big threat to us. Do the Government want us to be refugees in our own land? We have nowhere else to go. We don't want to go anywhere else. The Government should tell Tamboran to stop mining on Aboriginal Land.

I see the water in a big way. Were all connected to it. It doesn't matter what country we're on, every native title and land trust holder has a right to speak for water. Tamboran hasn't talked to native title or land trust holders who live downstream from their fracking sites. All native holders should have the say. They haven't included us in their thoughts and decisions about water. We are talking about survival of all people throughout our region.

[redacted]

From: No New Gas Coalition <nonewgas@gmail.com>
Sent: Tuesday, 9 January 2024 4:05 PM
To: tamboran DEPWS
Subject: No New Gas Coalition NT submission in response to: Tamboran Resources Ltd Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98
Attachments: Submission on TBN EMP_Jan2024_PR.docx.pdf; THE RISKS OF OIL AND GAS DEVELOPMENT FOR HUMAN HEALTH AND WELLBEING - A SYNTHESIS OF EVIDENCE AND IMPLICATIONS FOR AUSTRALIA.pdf

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

To Whom It May Concern:

Please find attached the 'No New Gas Coalition NT submission in response to 'Tamboran Resources Ltd Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98'.

Also attached is a meta analysis of more than 2,000 peer-reviewed publications from the last decade. Titled 'The Risks of Oil and Gas Development for Human Health and Wellbeing: A synthesis of evidence and the implications for Australia', it's a critical body of work for decision-makers, tasked with assessing gas industry submissions, to be aware of. It details the comprehensive risks of allowing the industry to progress that have come to light as a result of the remarkable research efforts in the United States, and increasingly in Australia as well.

This wide-ranging review including recent academic and research insights has only strengthened long-standing concerns regarding the multiple, complex risks of serious harm to human health and wellbeing associated with oil and gas development. New studies are emerging regularly, with deepening fears that reproductive consequences and increased cancer rates may be revealed in the future, with longer duration of human exposure to these multiple and unchecked potential harms. In addition to direct health risks, human health and wellbeing is threatened by the risks of contamination of air and water with a wide array of harmful chemicals, the excessive use of limited freshwater resources and substantial contributions to climate change should the proposed new developments progress. Human safety and security is also at risk.

The Report concludes with an urgent plea to all Australian governments to recognise the full extent of risk that this industry brings to our nation at a time when the dangers of climate change demand rapid reduction, not expansion, of fossil fuels to preserve our future.

Sincerely,

No New Gas Coalition NT
Location: Coconut Grove, NT
Stakeholder type: Non Government Organisation (NGO)
Interest areas: Social and cultural; Water; Climate change; Chemicals; Well integrity; Flora and fauna; Waste management; Human health; Regulation and compliance

No New Gas Coalition NT **submission in response to: Tamboran Resources Ltd Beetaloo Basin Shenandoah South E&A Program Environment Management Plan (TAM1-1) EP 117 and EP 98**

9 January 2024

The No New Gas Coalition NT is a growing NT based coalition of individual Northern Territory residents and organisations (including Climate Action Darwin, Environment Centre NT, Frack Free NT, Parents for Climate Darwin and NT). Our combined online reach extends to over 34,750 people.

The No New Gas Coalition aims to end new gas projects in the NT. Evidence-based decision making underpins the work and positions taken by the No New Gas Coalition in regards to the impacts of the gas industry on the climate, environment, human health, culture and communities.

Summary

As set out below, the Tamboran TAM1-1 draft Environmental Management Plan (**D/EMP**) does not comply with,

1. The requirements of the **Petroleum (Environment) Regulations (2016)**.
2. The requirements set out in the **Environment Management Plan Content Guideline - Onshore Petroleum Regulated Activities** (DEPWS 2022).
3. The requirements of the **Code of Practice Onshore Petroleum Activities in the Northern Territory** (2019).

The direct, indirect and cumulative impacts and risks of the proposal, to the extent they have been set out in the D/EMP, are clearly not environmentally sustainable or capable of being approved as environmentally acceptable. **For these reasons the Minister is obliged to reject this D/EMP and the proposal.**

Timing of release

The timing (Christmas/New Year holiday season) of the release for public comment of Tamboran Resources Ltd's D/EMP erodes public trust and confidence in relation to the assessment and regulation of fracking for fossil methane gas in the Beetaloo sub-basin. A formal request to the Minister from a community organisation to extend the public comment period was denied. We strongly recommend amending the relevant legislation to enable the Minister to grant extensions to public comment periods.

1. Requirements under relevant legislation and regulation

As set out in regulations 8 and 9 and Schedule 1 of the Petroleum (Environment) Regulations (2016), the D/EMP MUST include or satisfy the following requirements:

- *a **description of the regulated activity** to which the plan relates*
- *be **appropriate for the nature and scale** of the regulated activity to which the plan relates*
- *address **all direct and indirect environmental impacts and risks***
- *address the **cumulative effects** of those impacts and risks*
- *provide **comprehensive information** about all relevant matters*
- ***demonstrate** that the activity will be carried out in a manner by which the environmental impacts and environmental risks of the activity will be reduced to a level that is (a) as low as reasonably practicable and (b) acceptable.*

2. Failure to adequately address scale and associated risks of major hazardous industry project

Contrary to the requirements of the legislation, the D/EMP fails to provide comprehensive information that is appropriate to the nature and scale of the project to enable an assessment of the project's impacts and risks.

- The proposal outlined in the DEMP amounts to a major, hazardous industrial project in a remote region of the Northern Territory which is increasingly experiencing extreme temperatures and severe heatwaves, large scale bushfires and high intensity rainfall events.

- The project would occur within a jurisdiction, the Northern Territory, which has repeatedly demonstrated limited and inadequate capacity for the environmentally responsible regulation of large scale hazardous extractive projects.

- The NT government has made clear its political determination to rapidly proceed with fracking across the Beetaloo in spite of its failure to implement the recommendations of the Pepper Inquiry[1] and the SREBA study.[2]

- The overall project, including well sites, pipelines and roads, would involve surface and sub-surface impacts across a gross area of some **400 sq km**, within the catchment area of the ecologically significant Newcastle Creek and Lake Woods.

- The project would involve **hundreds of 'B-triple' heavy truck movements**, carrying chemicals, contaminated wastewater, sand (proppant) etc, along highways and dirt roads to access each of the five well sites (Kyalla 117 N2; Shenandoah S2; Shenandoah SB; Shenandoah SC; Shenandoah NA).

- At p103 the D/EMP states that each well will require "2.5 ML per E&A well for drilling and completions and 72.0 ML per well for stimulation". Across 15 wells this amounts to **1,117.5 ML** of groundwater (or **1.117 BILLION litres of groundwater**).

- Based on the table provided (Table 6, '3 well totals') the 15-well project would entail the transport, storage and pumping down-well of a total of ~**10,000,000 litres/kilograms** of fracking chemicals (excluding sand/proppant). At least **33** of the chemicals could be '**high concern**' due to potential toxicity.[3]

- Based on figures provided in the EMP, including the stated "15% recovery of fracking fluid" (p109), the project would involve the generation, storage, movement and disposal of over **180 million litres** of **contaminated wastewater** (22.5 ML drilling fluids; 162 ML recovered fracking fluids).

- If as stated only 15% of chemical-laced frack fluid is recovered per well, this means **0.85 x 10,000,000 = 8,500,000 litres/kilograms** of fracking chemicals, many of them toxic, will remain underground in fractured geological formations.

- The project would involve groundwater extraction of some **375 ML/year** from the Gum Ridge Formation, without adequate impact/risk assessment or monitoring.[2,4] The Anthony Lagoon and Gum Ridge formations are the two major aquifers in the Cambrian Limestone Aquifer within the Georgina Basin.

> *There remain substantial knowledge gaps regarding the geological architecture of the SREBA area, from the deep Beetaloo Basin rocks through to the shallow Cambrian and Cretaceous aquifers...The 2021 review also noted that there was a 'poor' understanding of inter-aquifer connectivity across all of these units and the **Gum Ridge Formation**, and 'moderate' to 'poor' understanding of aquifer hydrogeological parameters in these units.*[4]

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[1] *Final Considerations* letter to Chief Minister from Dr David Ritchie, Independent Oversight Hydraulic Fracturing Implementation (2023).

[2] Final technical report of SREBA (DEPWS, Dec 2022) which includes numerous recommendations for further and improved assessment, monitoring and ecosystem protections **which the NT government has completely ignored.** See: *Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin (41/2022)*

[3] "An environmental risk assessment was undertaken during the GBA Program of 116 chemicals associated with drilling and hydraulic fracturing operations in the Beetaloo region, **of which 33 were of potentially high concern**. Future groundwater monitoring programs aimed at detecting contamination from onshore gas activities should be informed by identified chemicals of potential concern." SREBA final report (2022)

[4] SREBA Expert Review – Groundwater. Professor Matthew Currell and Dr Christopher Ndehedehe. Accessed at: www.ecnt.org.au/reports

- The D/EMP proposes the installation and operation of 17 kilometres of plastic (polyethylene) piping to create a 'gathering network' to transfer contaminated wastewater and methane gas between well sites. **The adoption of this high risk activity is based at least in part on cost-cutting by Tamboran**.

- Although Tamboran attempts to confuse the actual numbers, the proposal would generate approximately (at least) **~954,000 tCO2-e greenhouse gas emissions over four years.**

3. Failure to present and address key project components, impacts and risks

3.1 Large scale sand (proppant) mining, washing and transport

The 'Description of Activity' (Table 1) fails to include the mining, washing and transport of sand (proppant) – a major part of this proposal involving up to **56,250 tonnes** of sand and millions of litres of water.

At page 85 the proponent states, "*Proppant will be sourced from locations within Australia (such as South Australia) or imported from international sources*."

In breach of the statutory requirements discussed above, the D/EMP avoids any assessment of the significant impacts of the sourcing, washing and transport of sand (proppant), including water use, transportation and greenhouse gas emissions.

The D/EMP also fails to include or address the impacts of the proponent's recently announced plans to mine sand for the proposal:

> *"In light of the Strategic Partnership, Tamboran, via its subsidiary Tamboran Infrastructure (TBI), has applied for 14 extractive mineral exploration licences in close proximity to the proposed Shenandoah South Pilot Project for the evaluation of and future extraction of frac sand. The Strategic Partnership with Liberty and mining of local sand are two initiatives that are expected to support material reductions in stimulation costs for future development programs."*
> Tamboran ASX announcement, 15/12/2023.
> https://www.investi.com.au/api/announcements/tbn/0a3ee27e-cdf.pdf

In order to comply with the statutory requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of the mining, washing and transport of sand (proppant), including water use, transportation and greenhouse gas emissions, and an assessment of their impacts, needs to be presented and be subject to informed assessment.

3.2 'Gathering network' of polyethylene pipes for wastewater and methane gas transfer

Despite being barely mentioned in the D/EMP, the proponent is proposing **TWO** 'gathering networks' of polyethylene piping to transport wastewater and hydrocarbons between well sites **over a combined distance of ~17 km**.

For much of the D/EMP it appears there is just one such gathering network, for wastewater, amounting to **"~8.61 km**" of plastic pipelines.

For example, in "*Table 1: Description of the proposed new exploration and appraisal activities for the Shenandoah South E&A program, including 2D seismic acquisition*"**,** there is only reference to the "~8.61 km wastewater gathering lines", and there is no mention of a **separate, dedicated, hydrocarbon, i.e. methane gas, gathering line or network**.

Even where 'hydrocarbons' is mentioned, it is not clear that two separate gathering networks are being proposed.

> P1: *"**Construction of a gathering network connecting exploration sites** to allow for the transfer of wastewater (including raw water, flowback, completion and drilling wastewater) **and hydrocarbons between** Kyalla 117 N2 and Shenandoah S2 and Shenandoah S B and Shenandoah S C.*

Only on **page 62** of the D/EMP does it become clear that two separate gathering networks of polyethylene pipes are being proposed:

> ***3.6.6 Gathering network construction***
> *Gathering lines will be constructed as required to facilitate the transfer of **high volumes of fluid and produced hydrocarbons** safely and efficiently between well pads to a centralised storage area to enable centralised management and fluid recycling (Figure 16). The gathering lines will be constructed at the following locations:*
> *• Shenandoah S B to / from Shenandoah S C: **~4.108 km** (4.11 ha)*
> *• Kyalla 117 N2 to / from Shenandoah S2: **~4.5 km** (4.50 ha)*
>
> *Gathering lines will be constructed, operated, maintained and abandoned in line with the "Code of Practice for Upstream Polyethylene Gathering Lines in the CSG Industry and Companion Papers", August 2019 (APGA 2019). It is anticipated that **up to two (2) buried low-pressure (~1,500 kPag) 6-inch polyethylene gathering lines will be utilised; one managing water and one managing hydrocarbons**. A single co-mingled gathering line **may also be utilised** where practicable.*
>
> *Beneficial outcomes of installing and operating a gathering network include: ...Reduced capital and operational costs.*
>
> ***In some cases, an above-ground gathering line for fluid transfer may be utilised instead of a buried gathering lines* (sic)**. *Above ground gathering lines will be temporary and typically used for several months before being purged and decommissioned.*

Even when a second, parallel network of plastic pipes for hydrocarbons is finally mentioned, there is no acknowledgement that the total gathering network will involve ~17 km of buried and above-ground pipes.

There is manifestly insufficient information in the D/EMP about the operation, impacts and risks of the proposed **2 x 8.6 km** 'gathering network' of polyethylene pipelines transferring wastewater and hydrocarbons from well site to well site across the project area.

The exact composition and volumes of the wastewater and hydrocarbons proposed to be moved across the landscape via the plastic pipe network is not clearly presented.

There is insufficient information regarding the extent and location of above-ground versus underground configuration.

This is the first time such a network of plastic pipes carrying toxic and hazardous materials has been proposed in the Beetaloo and it raises serious issues that have been ignored or downplayed in the D/EMP. This includes the risk of methane leakage, the risk of fire or explosion and the risk of contaminated wastewater leakage resulting in pollution of streams and wetlands.

The risk and consequence of methane gas or liquid hydrocarbon leakage from the gathering network igniting during bushfire emergencies is not adequately addressed or assessed in the D/EMP – in a region experiencing increasingly severe fire weather and extensive, long-duration bushfires as a result of climate change.

Tamboran purports to set out a complex operational management system to guard against damage, leaks and spills from the 'gathering network' but based on the company's record of multiple reportable and recordable incidents at its existing fracking well sites (see below), the safe management of such a complex and extensive system cannot be assured.

In order to comply with the requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of the two proposed polyethylene pipe networks needs to be presented and be subject to informed assessment.

3.3 Down-well 'loss' of millions of litres of drilling fluid and frack fluid

At p103 the D/EMP states that each well will require "2.5 ML per E&A well for drilling and completions and 72.0 ML per well for stimulation". Across 15 wells this amounts to 1,117.5 ML of groundwater (or 1.117 BILLION litres of groundwater).

The D/EMP makes passing reference to the likely loss of millions of litres of drilling fluids and fracking fluids at each well due to the nature of the geological formations being accessed via this proposal.

On p79:

> *3.7.3 Drilling*
>
> ***Commonly during the drilling of the Gum Ridge Formation (GRF), partial to total losses of drilling fluid have been observed due to high permeability conduits, fractures and cavernous zones expected in karstic formations**. Loss of circulation material (LCM) is typically used to respond to fluid losses, **with additives used to block fluid pathways to re-establish fluid circulation**. LCM is often in the form of viscosity enhancers (such as bentonite and polymers), fibrous material (such as coconut coir, nut hulls etc.) or granular material (such as marble chips) with the type of LCM used dependent on the level of losses and formation type. Where drilling fluid losses cannot be stopped, the drilling fluid systems are reduced back to water to maintain dynamic well control (a continuous supply of water to overcome formation pressures) and to minimise drilling additive losses to the formation. Once the zone of high losses has been drilled through on water, the section is then cased-off to regain fluid circulation and allow drilling to continue unimpeded. **It is anticipated that LCM will be utilised and there is a potential that casing off high loss zones will be deployed to manage fluid losses for the additional wells proposed under this EMP.***

On page 155:

> *4.1.8 Hydrogeology*
>
> *The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Beds, is an extensive, multi-layered regional aquifer system covering at least 200,000 km2 that forms the principal water resource in the Beetaloo Sub-basin, (SREBA, 2022).*
>
> *The CLA is a **highly productive aquifer** that has **high regional connectivity** due to the development of **significant fracture and karstic secondary porosity** (SREBA, 2022). Across parts of the Beetaloo Sub-Basin, undifferentiated Cretaceous deposits form the uppermost aquifer are targeted for stock use. Notably, a basal sandstone unit immediately overlying the CLA produces yields of at least 10 L/s (SREBA, 2023). Shallow, perched groundwater has also been recorded in the laterised zone within the permit area with groundwater levels recorded between 1 and 6 mBGL. These systems are dynamic with periodic saturation resulting from recharge during the wet season with no documented groundwater use. **The CLA, comprising the Gum Ridge Formation and the Anthony Lagoon Formation, is an extensive regional aquifer system that forms the principal water resource in the Beetaloo Sub-Basin.** Near the Kyalla 117 N2 site, for example, both aquifer units have a standing water level of approximately 114 m below top of casing. **The limestone in the CLA is commonly fractured and cavernous**; in the Katherine region, bore yields of up to 100 L/s have been recorded from this aquifer (SREBA, 2023). Such high yielding sections were encountered when drilling the Kyalla 117 N2-1 E&A well through the Anthony Lagoon and Gum Ridge Formation, **with total losses of drilling fluid circulation at specific intervals**.*

On p109:

> *3.12.3.1 Volume*
>
> *Tamboran anticipates that a potential load fluid recovery of **15%** of injected stimulation fluid over the testing duration based upon previous Amungee NW-1H results.*

If only ~15% of frack fluid is recovered, this means that, in addition to the loss of much or all of the drilling fluid, each proposed well will result in 0.85 x 72 ML = 61.2 ML of chemical-laced frack fluid remaining underground. Across 15 wells this amounts to 918 ML (almost 1 BILLION litres) of chemical contamination.

No information is provided in the D/EMP as to the **potential cumulative impacts and risks** of this quantity of chemical-laced drilling and fracking fluid remaining underground post-fracking. If this project proceeds and hundreds more wells are drilled and fracked as planned, the potential cumulative load of contaminated water remaining underground would run to hundreds of billions of litres.

An insight into what may be occurring with fluid use and loss at Tamboran's existing wells can be found in a research report by Hannam and Partners commissioned by Tamboran and found on the company's website[5]:

> *The [Amungee 2H] well is currently producing 65bbl/d of water with a cumulative 17,879 bbl of water recovered to date. Gas flows from the well are yet to establish 30-day initial production (IP30) rates with only* ***~10% of the water used in the stimulation program recovered to date.***
>
> *The result was clearly not what was expected but TBN is very confident that it was not a geological issue. The confidence is demonstrated by TBN going back to drill another development well at Amungee.* ***The possible "skin" preventing higher gas flow*** *is thought to be because of bacterial formation as the frac water was left too long and not sufficiently treated - a key learning for future wells.*
>
> ***Also, the shale is highly desiccated, one of the driest in the world, which means that frac fluid will be absorbed into the shale and not flow back****. A shale reservoir can undergo a process called water imbibition during the frac process: the absorption of water by the shale formation when it meets the frac fluid. The water can penetrate the shale matrix and fill the pore spaces within the rock. The imbibed water can have several effects on the shale reservoir.* ***First, it can cause swelling of the shale rock, leading to an increase in pore pressure and changes in rock properties. This can impact the permeability of the formation and alter fluid flow characteristics. Second, the imbibed water can affect the geo-mechanical behaviour of the reservoir, potentially leading to changes in rock stability and induced stresses.***[6]

The Hannam report indicates what the potentially serious risks of this loss of huge volumes of fluid may be, but there is no discussion of this in the D/EMP, again breaching the requirements of the regulations.

In order to comply with the statutory requirements of the relevant legislation and regulation, a full, unambiguous description of all aspects of the mining, washing and transport of sand (proppant), including water use, transportation and greenhouse gas emissions, and an assessment of their impacts, needs to be presented and be subject to informed assessment.

3.4 Greenhouse gas emissions

In this D/EMP the company uses various accounting (and discounting) techniques to confuse and understate the emissions from this project. Table 23 – "***EMP anticipated greenhouse gas emissions breakdown per financial year, including offset requirements*****" –** is a clear case of deliberate confusion as to the project's actual emissions**.**

In summary,

- The company fails to clearly state the project's full lifetime emissions, including scope 3 emissions;
- The company fails to include emissions from key project components including mining and transport of huge quantities of sand (proppant) and disposal of large volumes of wastewater;
- The company attempts to 'reduce' emissions by claiming a discount for the possible future 'beneficial use' of gas;
- The company potentially overstates the efficiency of flaring in reducing emissions;
- The company proposes to conduct only 6 monthly methane leak detection activity, meaning significant methane fugitive emissions could occur without detection.

    - P120: *"**Six monthly** routine leak detection and repair program to detect, repair and report leaks to be implemented (D.5.3)."*

[5] Hannam and Partners (27 June 2023). *Capital raise to unlock Beetaloo Basin development*. www.tamboran.com/research-reports

[6] Hannam and Partners (2023).

- Table 24: Greenhouse gas calculation for the proposed activities

Table 30: Monitoring program summary

Monitoring program	Purpose	Monitoring points	Parameters	Frequency	Investigation thresholds	Reference document
Methane emission monitoring program	To identify and remediate gas leaks	Each exploration well	Methane (PPM)	6 monthly	>500 PPM	MEMP (Appendix I)

3.4.1 Actual emissions

Using various confusing accounting and discounting techniques, Tamboran claims its total emissions for this 15 well project amount to "400,011 tCO2-e". (Table 23).

In fact, based on information provided elsewhere in the D/EMP, the emissions outcome is very different.

- **FY24:** Based on Figure 5 (p42) setting out the timing of activities, **FY24** has no fracking and well testing activity, just well drilling (2 wells). The stated emissions (table 23) are 24,662 **tCO2-e.**
- **FY25:** Based on Figure 5 (p42), FY25 has **3 wells** scheduled for fracking and testing/flaring. The stated emissions are **190,838** t**CO2-e.**
- If three wells fracked and tested/flared produce 190,838 tCO2-e then 15 wells as proposed would be expected to produce a total of **~954,000 tCO2-e**.

~954,000 tCO_2-e is more than double the total emissions stated by Tamboran in the D/EMP. Across the four years listed by Tamboran (Table 23), this amounts to an annual average level of emissions of 238,500 tCO_2-e.

If indeed the fossil methane gas is piped to another location and burnt as fuel as part of some possible future 'beneficial use' regime, the actual amount of emissions will remain the same as if it were burnt (flared) at the well site. Indeed, there may be greater emissions in the 'beneficial use' scenario if fugitive methane emissions along the pipeline transport route are significant.

Either way, the D/EMP grossly understates the emissions from this project. Consequently, all the D/EMP's subsequent misinformation about offsets, net zero, Safeguard Mechanism implications, etc, cannot be relied upon.

Based on its annual emissions, **238,500 tCO_2-e**, this proposal clearly falls within the scope of the NT government's 'Large Emitters Policy' which,

> *"Applies to new projects and expansion of existing projects that are considered to be 'large emitters'. The Large Emitters Policy defines 'large emitters' as projects that meet or exceed emissions thresholds:*
>
> - *The industrial project threshold is **100 000 tonnes carbon dioxide equivalent (tCO2-e) (scope 1) in any financial year** over the life cycle of a project.*

3.4.2 Cumulative carbon pollution from Beetaloo fracking

In section 3.17.1 of the D/EMP Tamboran makes various unsupported and unsubstantiated claims about emissions intensity, offsets, net zero, gas as a transition fuel, etc. But nowhere does the D/EMP address the full scale of emissions expected from the development of the Beetaloo sub-basin, and the fact that it will not be possible to abate these emissions using credible carbon offsets or reliable carbon capture and storage (CCS/CCUS).

Contrary to the unsubstantiated claims made by Tamboran in the D/EMP, recent reports have highlighted:

(a) the extreme level of emissions expected to be produced through full development of the Beetaloo sub-basin, if precursor E&A projects such as Tamboran's current 15-well proposal are approved:

*The lifecycle greenhouse gas emissions resulting from Tamboran's current development plans, in line with the CSIRO GISERA scenario 1 (scenario 1b), would amount to between **33 and 47 million MtCO2e annually**, accounting for **7 and 10% of Australia's 2021 total emissions**. Over the 25-year lifetime of the project, this represents between one and a half to two times Australia's 2021 emissions.*

Climate Analytics (2023). *Emissions impossible: Unpacking CSIRO GISERA Beetaloo and Middle Arm fossil gas emissions estimates*.

(b) the inability of emissions offsets to abate the emissions involved, due to the amount required, the cost and the lack of suitable offsets with integrity:

*In calculating the carbon costs for a broad range of Beetaloo sub-basin development scenarios, from 200 TJ/day to 3,400 TJ/day, outcomes indicate that – in each case – the overlay of carbon costs to offset the Australian component of lifecycle emissions implies a **high risk of developed shale gas assets becoming economically stranded**.*

*An interim report from CSIRO's Gas Industry Social and Environmental Research Alliance into the use of offsets for lifecycle GHG emissions for onshore gas in the NT has similarly signalled that, "**the cost of offsetting Australian emissions from consumption of NT gas would be prohibitive**" for scenarios considering offsetting more than 200PJ/year (548TJ/day) of domestic consumption (GISERA2021).*

Reputex Energy (2021). *Analysis of Beetaloo gas basin emissions and carbon costs*. Australian carbon advisory, September 2021

(c) the world-wide failure of carbon capture and storage (CCS) as an abatement strategy:

Conclusion: Failed/underperforming projects considerably outnumbered successful experiences

The immediate inference from the projects reviewed is that the number of failures and the underperformance of these projects with carbon capture technology has outnumbered the successful projects considerably. Ten of the 13 flagship projects reviewed, comprising 90% of the total capture capacity in our sample, have failed or are underperforming mostly by large margins...Further, recently published research by the Imperial College London on the capture performance of operating projects since 1996 confirms the underperformance of most projects against their designed/claimed capture capacity...Successful CCUS exceptions mainly existed in the natural gas processing sector serving the fossil fuel industry, leading to further emissions.

Institute for Energy Economics and Financial Analysis (2022). The Carbon Capture Crux: Lessons Learned

(d) statements from leading global bodies including IPCC, United Nations and IEA that development of large new fossil fuel basins, such as the Beetaloo sub-basin, is not needed and cannot proceed if the world is to avoid catastrophic climate change.

As a result of the failure of the D/EMP to comprehensively and accurately present the carbon emissions and climate impacts and risks of the proposal, the D/EMP is again in breach of the relevant legislation and regulations.

3.5 Chemical threats to air quality

Section 6.6.3 of the D/EMP aspires to *"No significant impact on air quality… resulting from Tamboran's exploration activities"*. However in regards to air quality, in the associated Risk Assessment in Appendix M, only diesel is referenced as a risk source. Cursory mention is given to emissions of nitrogen oxides, carbon monoxide and volatile organic compounds (VOCs) where it's identified that they *"are small and not anticipated to reduce ambient air quality as there are no regional sources"*.

No mention is made of the vast array of other chemicals that are known to be released into the air during all steps of the fracking process, including but not limited to: polyaromatic hydrocarbons, radioactive materials, hydrogen sulphide, acrolein and heavy metals.

It is known through the body of scientific literature assessing the potential local, regional and global health-related impacts associated with this industry (more than 2000 peer-reviewed publications within the last decade, see Haswell *et al.*, 2023), that a cocktail of additional chemicals form in the atmosphere, including formaldehyde, particulate matter from aerosols and ground level ozone, which travel long distances damaging health and agriculture.

In light of the weight of this scientific evidence and Tamboran's failure to acknowledge the risks of these known associated chemicals, Tamboran's "Low" Residual Risk Rating is unjustifiable. The D/EMP's alarming assessment that "*impacts to sensitive receptors are not anticipated,... (That) flares will be utilised to minimise the release of VOC's. (That) the potential consequence from E&A activities is predicted to be minor. (That) the likelihood is a function of source (lack of) and separation distance between receptors. (That) the likelihood of a sensitive receptor being exposed to emissions from E&A activities above the NEPM guidelines are remote (<1%)*", is entirely inconsistent with the evidence that significant chemical sources of concern will be released. The D/EMP's self-assessed achievement of ALARP criteria is unconvincing and the self-assessed 'Scientific Uncertainty Ranking' of 'Low' is demonstrably false.

As a result of the failure of the D/EMP to comprehensively and accurately address the body of scientific literature that would have Tamboran define risk scenarios and sources for these chemicals and, if possible, present rigorous risk mitigation measures, the D/EMP is again in breach of the relevant legislation and regulations.

3.6 Chemical Threats to human and community health and wellbeing; and human health risk assessments

Neither of the consultants who have provided the chemical risk assessments (AECOM and EHS Support) are medical bodies or agencies specialising in human health and wellbeing. They are therefore not qualified to make determinations on the effects on human health of the chemicals proposed.

Were they qualified, they would be explicit about the, "*substantial quantity of increasingly rigorous research evidence (that) has accumulated from studies across oil and gas basins, especially in the United States of America… Finding(s indicate) a greater burden of health loss among those most exposed to oil and gas operations and infrastructure.*

Reported health risks include:

- *increased severity of asthma in children demonstrated by elevated incidences of exacerbations requiring medical treatment*
- *crises requiring emergency department visits and hospitalisations*
- *higher hospitalisation and death rates due to heart attacks, heart failure, respiratory diseases and some cancers associated with oil and gas operations and/or predicted from air pollution exposure in many studies across whole populations*
- *higher injury and fatality rates from increased large truck traffic volumes*
- *higher incidences of depression, anxiety, social withdrawal among young females and*
- *higher prevalences of sexually transmitted infections,*

linked to the impacts of oil and gas operations on home and community life.

Furthermore, multiple studies have detected interference with normal development of unborn babies. This includes higher risk of low birth weight, preterm delivery and spontaneous abortion, severe birth defects and risk of acute lymphoblastic leukaemia. Many studies have demonstrated that these outcomes occurred after, not before, gas

development commenced, while others have shown that these outcomes specifically occur downwind and/or downstream (groundwater flow) of gas operations. Most studies have controlled for a wide range of potential confounders (other explanations for the observed differences)."

(Haswell *et al.*, 2023)

(Of further concern is the) "*loud warning about the risks of sexual violence that have been suffered by First Nations Americans and Canadians associated with oil and gas activities interfering with their remote communities.*" (Haswell *et al.*, 2023). These risks have been completely ignored in Tamboran's assessment of potential consequences borne by local Traditional Custodians.

Tamboran's failure to include a full human health risk assessment in the D/EMP, as required by the Petroleum (Environment) Regulations 2016, conducted by qualified medical professionals, renders it in breach of the relevant legislation and regulations. When considering whether or not to approve the EMP, the Minister for Environment is duty-bound to seek out reliable medical opinions and acknowledge the body of evidence detailing the impacts on human health of the proposed activities.

3.7 Protection of water resources

Based on D/EMP table 35, p154, Tamboran proposes to drill through **seven (7) aquifers** in order to access the target 'Velkerrie' formation.

Table 35: Summary hydrostratigraphy based on encountered depths at Kyalla 117 N2

Province	Period / age	Formation		Aquifer status	Encountered Depths[1] (approx. top and bottom) (m)
CARPENTARIA BASIN	CRETACEOUS 145 – 66 Ms	Undifferentiated		Local-scale aquifer	0 – 70.0
GEORGINA BASIN	CAMBRIAN 497 – 630 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Formation	Regional aquifer	70.0 – 191.4
			Gum Ridge Formation	Regional aquifer	191.4 – 399.5
		Antrim Plateau Volcanics		Regional aquitard	399.5 – 499.0
		Bukalara Sandstone		Local aquifer (not regionally connected)	499.0 – 506.7
BEETALOO SUB-BASIN (ROPER GROUP)	UNKNOWN	Hayfield formation		Regional aquifer	506.7 – 899.33
		Jamison Sandstone		Local aquifer (not regionally connected)	891.33 – 988.97
	MESO PROTEROZOIC 1,430-1,500 Ma	Kyalla Formation		Regional aquitard	988.97 – 1851.75
		Moroak Sandstone		Local aquifer (not regionally connected)	1851.75 – not determined
		Velkerri Formation		Regional aquitard	700 – 900
		Bessie Creek Sandstone		Local aquifer (not regionally connected)	450

P155:

> ***Limited information exists on the hydrogeological characteristics of the deeper Roper Group and undefined Neoproterozoic group sequence*** *is available as it occurs at depth within the Beetaloo Sub-basin. This unit lies below the Georgina Basin which contains the CLA and other important aquifers. The deeper sandstone dominated formations* ***may behave as aquifers****, however, drilling results suggest these formations have limited potential as groundwater resources due to their depth and very high salinity. Groundwater in the Roper Group and undefined Neoproterozoic group is highly saline (>100,000 mg/L chlorides) and contrasts with the shallower, utilised aquifers of the Georgina Basin sediments in which groundwater is generally of drinking water quality.*

An independent expert review of SREBA groundwater studies and knowledge has concluded:

> *A further issue is that there do not appear to be monitoring data collected from within the Mesoproterozoic* ***Roper Group*** *sediments – which are the rocks targeted by the gas industry - aside from some previously*

published data in Fulton and Knapton, (2015). ***This is important, as assessment of connectivity between target units for hydraulic fracturing and the overlying aquifers, requires analysis of vertical hydraulic gradients between these formations.***

...

It should be stressed that the mapping of areas of ***potential deep-shallow aquifer connectivity*** *(e.g. Figure 4 of Tickell, 2022) is based on a small number of deep bores, and there remains* ***considerable uncertainty*** *as to the extent, thickness and hydraulic properties of the* ***deep aquifer units and intervening aquitards below the CLA, down to the Beetaloo basin rocks****, and presence / absence of geological structures. A program of geological, geophysical and geochemical investigations (e.g., encompassing deep drilling and rock/sediment analysis, seismic and electromagnetic surveys, isotopic and hydrochemical vertical profiling and vertical head gradient analysis)* ***is required to resolve this****.*[7]

Clearly, in the absence of crucial hydrogeological information as set out above, the proponent cannot claim to adequately understand the impacts or assess the risks of its proposed drilling and fracking operations.

The potential groundwater risks of this project are not addressed in the D/EMP, in breach of the relevant legislation and regulations.

3.6 Contaminated wastewater management – high risk strategies to reduce costs

The company claims that through the use of the proposed gathering network of plastic pipes, there will be a reduced requirement for wastewater storage tanks at each site:

3.6.6 Gathering network construction

Beneficial outcomes of installing and operating a gathering network include:

- *Ability to utilise existing installed wastewater containment and wastewater treatment capacity*
- ***Reduced land clearing for storage tanks at each well site***
- *Reduction in potential environmental impacts and risk from contaminant spills / releases*
- *Increased capability and capacity for recycling and reuse of fluids between well sites reducing groundwater take*
- *Reduced wastewater disposal volumes and truck movements*
- ***Reduced capital and operational costs***
- *Centralised flaring and hydrocarbon management to minimise light pollution from multiple sources.*

This strategy, to cut costs by reducing wastewater storage tanks based on the successful operation of the 8.6 km network of plastic pipes, is very concerning and shows the company is prepared to gamble with the environment in order to reduce costs.

If there are large or multiple failures in the plastic pipe network, in a severe rainfall event, the reduced storage tank availability may result in large scale contaminated water releases to the environment.

Such a high risk strategy, using untested plastic pipe networks to replace wastewater storage tanks, cannot be approved.

Not only is the company proposing to gamble with the environment to reduce costs in relation to wastewater storage tanks, but it is also leaving open the option of using cost-cutting approaches to pipeline and sump lining materials. If the materials identified are the best 'fit-for-purpose' materials, they must be used.

3.6.6.2 Material selection
Materials used for the construction of the gathering network will comply with section 3 of the PEGN Code. ***It is anticipated*** *that High Density Polyethylene (HDPE 100) will be utilised for all pipelines, due to their high toughness, excellent resistance to slow crack growth and rapid crack propagation. They also have an*

[7] SREBA Expert Review – Groundwater (2023). Professor Matthew Currell & Dr Christopher Ndehedehe. Accessed at: www.ecnt.org.au/reports

inherent resistance to water and many chemicals. HDPE pipelines are the material of choice for many water, wastewater, gas and other applications.

...

3.12.2.1 Sump design

An overview of the drilling sump design is provided in Appendix D. Each sump surface will be rolled and compacted, with a ***Coletanche liner*** *(****or equivalent****). Coletanche is a composite liner consisting of five different layers...*

Coletanche ***is anticipated to be used*** *based upon the following:*

- *easily installed and shaped to fit sump geometry*
- *high resistance to tearing/puncturing and to hydrostatic pressures*
- *low water permeability, with a 6 x10-14 m/s permeability*
- *can withstand high temperature fluctuations.*

In some circumstances, a conventional HDPE liner may be used*. Where a HDPE liner is used, the liner specification shall meet or exceed the Code requirements.*

3.7 Biodiversity impacts: Risks to nationally significant wetlands downplayed

Tamboran's D/EMP claims (p35):

> *"The activities that are the subject of the EMP* ***do not constitute threats of serious or irreversible environmental damage and there is no impact on the conservation of biological diversity and ecological integrity (principles 2, 4, 6 and 7). This has been confirmed*** *through various inquiries/ research program including the independent Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory and Commonwealth Geological and Bioregional Assessment Program."*

This claim is contradicted by the findings of the final report of the SREBA, which states,

> *Over 7000 records of 81 waterbird species from the study area were collated, and a total of 55 wetland sites was surveyed for waterbirds. All large-scale waterbird breeding events recorded from the study area, and the largest congregation of waterbirds,* ***were from Lake Woods and nearby waterholes on Newcastle Creek****. This area also has the highest concentrations of records of migratory shorebirds.* ***Smaller persistent wetlands in the Newcastle Creek drainage system and on the Sturt Plateau*** *support small-scale waterbird breeding events and are* ***likely to be refuges for waterbird persistence during dry periods****.*
>
> *...*
>
> *Many of the identified threats to these biodiversity values are already present in the landscape (habitat degradation, fragmentation and loss; competition and predation; invasive plants)* ***but could potentially be exacerbated by onshore gas development****. Others key potential threats from onshore gas development are* ***changes in surface water hydrology, reduction in groundwater availability, and contamination of surface or ground water****. Additionally, predicted changes under climate change scenarios — particularly increasing number of* ***very hot days and increasing evapotranspiration rates*** *— may reduce the resilience of terrestrial biodiversity in the study area, particularly species with a requirement for persistent water or climate-buffering habitats."*[8]

Given the very large quantities of contaminated wastewater being produced, transferred between wells sites via plastic pipes, stored in open tanks and trucked interstate, there is clearly a significant risk to the internationally significant wetlands of Newcastle Creek and Lake Woods. This risk has not been adequately presented or assessed.

[8] Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin. DEPWS Technical Report 41/2022.

3.8 Significant unexplained increase in planned groundwater use for fracking

Under this D/EMP Tamboran is proposing to extract and use,

P103:

3.11 Water supply and use

- **2.5 ML** per E&A well for drilling and completions
- **72.0 ML per well for stimulation**

In previous EMPs for operations in this region, targeting the same formation, water use for fracking per well has been given as around 25-45 ML:

*Amungee NW delineation program. Environment Management Plan (**ORI11-3**)*
p101:
*• **2.5 ML per E&A well for drilling** and completions (total 30 ML)*
*• **25 ML per well for stimulation** (total 300 ML)*

*Kyalla 117 N2 multi-well program **(ORI6-3)** Environment Management Plan*
p70:
*• **5ML per exploration well** for drilling*
*• **15 - 45ML per well** for stimulation and well testing activities*

*Beetaloo sub-basin multi-well drilling, stimulation and well testing program Environment Management Plan (**ORI10-3**)*
P92:
*• **5ML per E&A well for drilling***
*• **40ML per well** for stimulation*

Under this D/EMP, planned drilling and fracking water use has increased substantially to **74.5 ML per well**. No explanation is given as to why there has been a significant increase in groundwater requirements for fracking at these proposed wells.

Since, according to the D/EMP, only ~15% of fracking fluid is likely to be recovered, the company cannot claim that reuse or recycling of fracking fluid is going to result in any significant reduction in total water use for fracking.

The direct, indirect and longer term cumulative impacts of this massive increase in water demand have not been presented or considered in this D/EMP. This is a clear breach of the relevant legislation and regulations.

4. Tamboran's track record of well failures and multiple pollution incidents

Tamboran (including its subsidiary Sweetpea Petroleum) has a track record of multiple well failures (e.g., Amungee 1H and Amungee 2H wells) and reportable and recordable pollution incidents which are relevant to this proposal and must be taken into account in deciding whether or not to approve the D/EMP.

Based on its record to date in the Beetaloo, *over just a couple of years with a handful of wells*, the company cannot be trusted to operate safely and in accordance with the statements, claims and commitments set out in the D/EMP.

Some of the incidents set out below are believed to be still under secretive departmental investigation. The lack of transparency surrounding such investigations gives rise to further community mistrust as to the regulation of fracking in the Beetaloo.

Table: List of known, reported Tamboran frack well incidents and accidents in past 18 months.

1. Accidental spill of 1000 L of sodium bromide due to puncture of the IBC during handling.
Incident date: 20/4/23
Amungee 2H well on EP98.

https://depws.nt.gov.au/__data/assets/pdf_file/0003/1268067/amungee-multiwell-aepr.pdf

p.33*: "Tamboran has implemented several corrective actions following the 1000 L bromide spill that occurred on 20 April 2023. This spill was caused by a tyne puncture of the IBC during handling. Lessons include:*
• Ensuring a spotter to be used for all tote loading operations to avoid blind spots during handling
• A review of MPK's scope of work to ensure trained and competent people are provided for the tasks to be completed on site.
• Implementation of inspection process for bunding to ensure they remain fit for purpose

Recordable incident report:
https://depws.nt.gov.au/__data/assets/pdf_file/0012/1257996/tamboran-qtly-recordable-incidents-q2-23-beetaloo-multi-well-ep98-and-76-ori10-3.pdf
"During the relocation of a 1000L IBC containing Sodium Bromide from the delivery point to the mix tank, the operator misjudged the height of the tynes on the 5-tonne loader ***causing a spill to grade****. The chemical was stored in the covered laydown area awaiting bunding to be brought back into service as the* ***existing site bunding had been damaged during hydraulic fracture operations****. The bunds utilised are prone to tearing with pallets and loader tynes."*

2. Wastewater tank liner leakage resulted in ~800 litres of flowback water spilling onto the lease pad/hard stand (7/6/23)
Kyalla N2 well on EP 117
Date: 7 June 2023

https://depws.nt.gov.au/__data/assets/pdf_file/0006/1275243/kyalla-civils-and-d-d-aepr-oril-1-and-ori3-2.pdf

P. 33*: "One recordable incident occurred on 07 June 2023, resulting in ~800 L of flowback fluid spilling to the hardstand due to a compromised tank liner. The contaminated material was cleaning up and stored in the bunding awaiting disposal. The contaminated material did not infiltrate the environment... Lessons learned include increasing the tensile and puncture resistance of liners used for extended evaporation to reduce salt solid damage to the liner."*

3. Spraying of contaminated Beetaloo water for up to five days at wellsite on Tanumbirini Station
Date of incident: 01/10/2022
Maverick 1 gas well on EP136

Recordable Incident Report: Tamboran Resources (via subsidiary 'Sweetpea Petroleum'):
https://depws.nt.gov.au/__data/assets/pdf_file/0018/1183221/sweetpea-petroleum-limited-well-drilling-hydraulic-fracture-stimulation-and-well-testing-swp4-3.pdf

"Low EC drilling wastewater utilised for dust suppression: During the drilling of Maverick 1, the drilling sump was filled to accommodate predicted fluid losses... the weir separating clean water from wastewater was breached – mixing the freshwater with bore water... An email was sent from the Tamboran Operations Manager to the Field Operations team on 30
September 2022 directing them to work toward lowering the fluid level to below the freeboard level as a priority.
• On October 1, water was transferred from the southern sump cell (where drilling cuttings and muds had not been stored) to the turkey's nest and taken directly from the sump for use as dust suppression at the direction of the Onsite Company Representative (OCR);
• On 1 October, The Drilling and Completions Manager identified that water from the drilling sump had been used for dust suppression and immediately intervened to ensure it was not ongoing."

See also:
https://www.abc.net.au/news/2023-08-24/nt-contractors-accuse-tamboran-of-using-contaminated-water/102765872

https://www.lockthegate.org.au/allegations_tamboran_dumped_contaminated_drill_fluid_a_major_health_concern_for_nt_workers_cattle_industry

4. Pumping of contaminated water from a well site that was drilled (but not fracked) at Tanumbirini Station
Date of incident: 01/10/2022
Maverick 1 gas well on EP136

Recordable Incident Report: Tamboran Resources (via subsidiary 'Sweetpea Petroleum'):
https://depws.nt.gov.au/__data/assets/pdf_file/0018/1183221/sweetpea-petroleum-limited-well-drilling-hydraulic-fracture-stimulation-and-well-testing-swp4-3.pdf

"Fluid level within the Maverick 1 drilling mud sump was above the 1.3m wet season freeboard level... Additional bore water was incorrectly transferred into the mud sump in preparation for potential loss of circulation...Transfer was human error/oversight... ***Temporary "frac" tanks were brought onsite*** *to reduce the volume of drilling fluids entering the sump.* ***A wastewater tank was constructed onsite*** *to reduce the volumes in the sump to below the 1.3m freeboard level."*

See also:
https://www.abc.net.au/news/2023-05-22/questions-raised-about-the-largest-fracking/102379428

5. Failure of bund in heavy rainfall
Date of incident: 28 Nov 2022. Date of report: 23/02/23.
Maverick-1 well site on EP136.

Reportable Incident Report: Tamboran Resources (via subsidiary 'Sweetpea Petroleum'):

"*During the rainfall event of 27 and 28 November, stormwater flows accumulated in the southeast (SE) corner of the site where the bund ultimately failed (the failure point). It appears the southeast corner bund was unable to contain the velocity and/or volume of the stormwater from the rainfall event, resulting in the bund failing and releasing stormwater into the surrounding area...The EMP, erosion and sediment control plan and civil construction drawings did not have sufficient technical instruction/ information as to how the bunds were to be constructed to withstand* ***high velocity stormwater flows*** *due to the size of the lease pad*."

https://depws.nt.gov.au/__data/assets/pdf_file/0011/1219628/230223-sweetpea-sediment-release-final-report.pdf

6. Chemical spill
Maverick 1 well site on EP136
Date: 04/09/2022

Recordable Incident Report: Tamboran Resources (via subsidiary 'Sweetpea Petroleum'):
https://depws.nt.gov.au/__data/assets/pdf_file/0009/1153899/sweetpea-petroleum-limited-well-drilling-hydraulic-fracture-stimulation-and-well-testing-q1-july-to-sept-2022.pdf

"*6 each x 1T bulk bags of Calcium Chloride were damaged in transit. Some contents of the bulk bags (approximately 120kgs) had spilled onto the deck of the tautliner trailer deck while about 30kgs of material spilled onto the ground during the unloading of the bulk bags... The broken bags were noticed when the sides of the tautliner were pulled back in preparation for unloading.* ***Where possible, we stuffed rags into the holes in the bags to prevent any more material from running out***."

7. Drilling mud leak
Tamboran 'Shenandoah South 1H' well
12 am, 12/08/2023

https://depws.nt.gov.au/__data/assets/pdf_file/0005/1286636/tamboran-b2-pty-ltd-kyalla-multi-well-ori6-3.pdf

The derrickman and motorman were preparing mud for the drilling of the production hole section as per the Tamboran Mud Program for Shenandoah Sth#1. ***Drilling additives*** *were being loaded into the bulk hopper and pumped through to the additional mixing tanks for transfer into the Rig 469 mud tanks. During this process a 6" clamped hose separated spilling approximately 22 barrels (3,520 litres) of drilling mud to the ground. Both crew members were still working in the mixing area and immediately shut down the pumps.The spill was reported to the Tamboran Operating Company Representative (OCR) and clean up commenced immediately. Due to the viscosity of the fluid it did not soak into the surface and was able to be remediated using the vac truck on site along with shovels to scrape up the material from around the equipment (approximately 1m3). All material was disposed of in the drilling sump. The spill was contained within the Kyalla 117 lease pad (gravel surface).*

In addition to the above seven pollution and mismanagement 'incidents', Tamboran's problems at two of its previous wells, Amungee 1H (Origin Energy operator) and Amungee 2H, have never been properly explained, including in this D/EMP.

1. **Amungee NW 1H** (excerpt from Amungee EMP)**:**

*A **casing deformation** event within the Amungee NW-1H horizontal (i.e. within the Velkerri shale) was recorded during stimulation, however this was not considered a major hazard. This event resulted in poor production outcomes (**i.e. the production casing within the horizontal well installed within the Velkerri shale became damaged**).*

2. **Amungee 2H** (excerpt from Hannam and Partners research report on Tamboran website):

*The well is currently producing 65bbl/d of water with a cumulative 17,879 bbl of water recovered to date. Gas flows from the well are yet to establish 30-day initial production (IP30) rates with only **~10% of the water used in the stimulation program recovered to date. The result was clearly not what was expected** but TBN is very confident that it was not a geological issue... The possible "skin" preventing higher gas flow is thought to be because of bacterial formation as the frac water was left too long and not sufficiently treated - a key learning for future wells.*

5. Failure to comply with legislation, regulation, codes and guidelines

In addition to the failure to comply with the requirements for a D/EMP set out in the Petroleum (Environment) Regulations (2016), as discussed above, the D/EMP also fails to comply with the DEPWS 'EMP Content Guideline' and the **Code of Practice Onshore Petroleum Activities in the Northern Territory (2019)**.

5.1 Environment Management Plan Content Guideline - Onshore Petroleum Regulated Activities (2022)

It is important, therefore, that EMPs:

• are assessable by the Minister for Environment, through inclusion of:
- ***all required content under the Regulations***
- ***clear, systematic and rigorous identification of all environmental impacts and risks** based on **well-defined activity descriptions** and **reliable environmental information***
- ***clear demonstration of ALARP and environmental acceptability and how activities may be carried out in a manner consistent with the principles of ESD***
- *a fit-for-purpose implementation strategy that outlines the inspection, audit, monitoring and reporting programs that will be used to confirm the effectiveness of risk mitigation measures and measure and respond to environmental performance;*

• are auditable by the regulator, through inclusion of:
- ***measurable and specific environmental outcomes, performance standards, and risk controls***
- ***clearly defined scopes for inspections, audits and monitoring programs***
- *clear identification of regulatory reporting requirements under the Regulations and other applicable legislation.*

• are outcome based to allow interest holders flexibility as to how a regulated activity is undertaken

• clearly describe stakeholder engagement processes and outcomes, and how the EMP has been informed by consideration of impacts to stakeholders

• clearly explain to the public how activities will be carried out and how impacts and risks will be managed

***• incorporate the most up-to-date scientific research** into the NT's onshore gas industry available at the time.*

5.2 Code of Practice: Onshore Petroleum Activities in the Northern Territory (2019)

Based on the information provided, there are several areas where the requirements of the Code of Practice are not met:

- the discharge of wastewater and the use of open storages of wastewater;
- the requirement for six months of baseline data to be established from groundwater monitoring bores prior to drilling commencing;

- the requirement for "an auditable chain of custody system" for wastewater tracking, and,
- the requirement for the EMP to include, where onsite disposal of drill cuttings is proposed, "certification from a suitably qualified third party that the material is of acceptable quality for disposal to land by the proposed method."

5.3 Environment Protection Act (2019) – requirement for referral

Under the EP Act, a proponent must refer a proposal to the NT EPA if it has the potential to have a significant impact on the environment (including a variation to a proposal / action), or meets a referral trigger.

The proposal set out in the D/EMP is clearly a project with the potential to have a significant environmental impact on the environment within the meaning of s 11 of the *Environment Protection Act 2019:*

> A ***significant impact*** of an action is an impact of major consequence having regard to:
> (a) the context and intensity of the impact; and
> (b) the sensitivity, value and quality of the environment impacted on and the duration, magnitude and geographic extent of the impact.

Contrary to Tamboran's self-assessment and conclusion, that the proposal does not require referral to the EPA, the proposed action DOES require referral to the Environment Protection Agency (EPA) under s. 50 of the *Environment Protection Act 2019*.

If Tamboran fails to refer the proposal to the EPA, the EPA should 'call in' the proposal for assessment. Section 53 enables the NT EPA to call-in (request a proponent to refer) an action that is being taken and should be referred.

Conclusion

As cited in 'The Risks of Oil and Gas Development for Human Health and Wellbeing: A Synthesis of Evidence and Implications for Australia', Haswell *et al.*, 2023' there is "now extensive evidence demonstrating multiple direct and indirect health and wellbeing risks from oil and gas developments.

The report identifies and discusses an extensive body of recent, peer-reviewed scientific and public health literature (more than 2,000 publications from the last decade) on five areas of extreme concern, namely:
1: the procedural risks posed by oil and gas operations to biodiversity, water and food security,
2: contributions to the climate emergency,
3: the vast array of potentially harmful chemicals involved,
4: contamination pathways into water and air and
5: resulting physical, social, emotional, spiritual health losses associated with extensive disruption of life near oil and gas fields and its sprawling infrastructure."

For these reasons and those set out in this submission, Tamboran's D/EMP does not comply with legislative requirements for the approval of an Environmental Management Plan and, based on the incomplete and inadequate information provided, is environmentally unsustainable and unacceptable. Therefore the Minister is obliged to reject the D/EMP and the project.